NASA CR- 152430

76SDS4269
30 SEPTEMBER 1976

(NASA-CR-152430) EVAL SYSTEM CONCEPT DEFINITION. PARTIAL SPACELAB PAYLOAD, APPENDICES (General Electric Co.) 99 p HC A05/MF A01 CSCL 22B

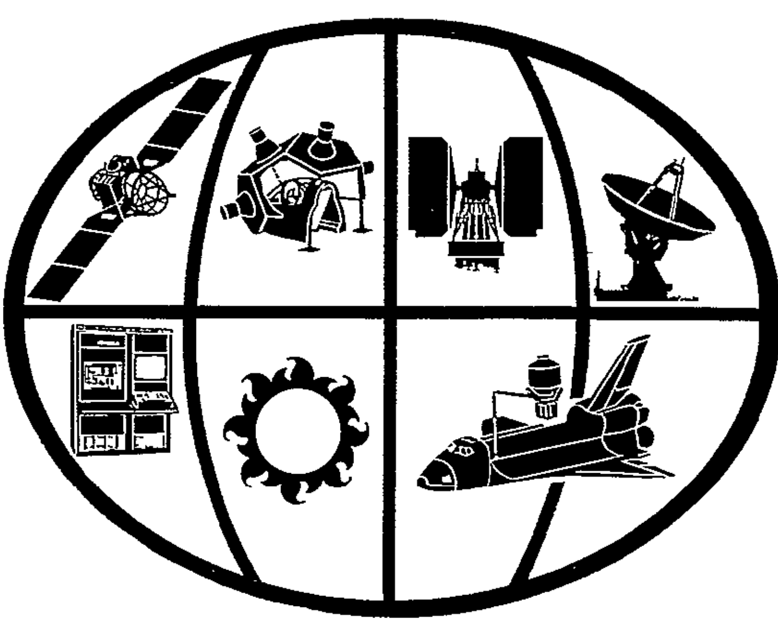
N77-18193

Unclas
G3/16 16318

EVAL SYSTEM CONCEPT DEFINITION

PARTIAL SPACELAB PAYLOAD

APPENDICES



space division

CONTRACT NAS 5-24022
AMENDMENT NO. 152

GENERAL ELECTRIC

76SDS4269
30 SEPTEMBER 1976

EVAL SYSTEM
CONCEPT DEFINITION

PARTIAL SPACELAB PAYLOAD
APPENDICES

CONTRACT NAS 5-24022
AMENDMENT NO. 152

GENERAL ELECTRIC

SPACE DIVISION

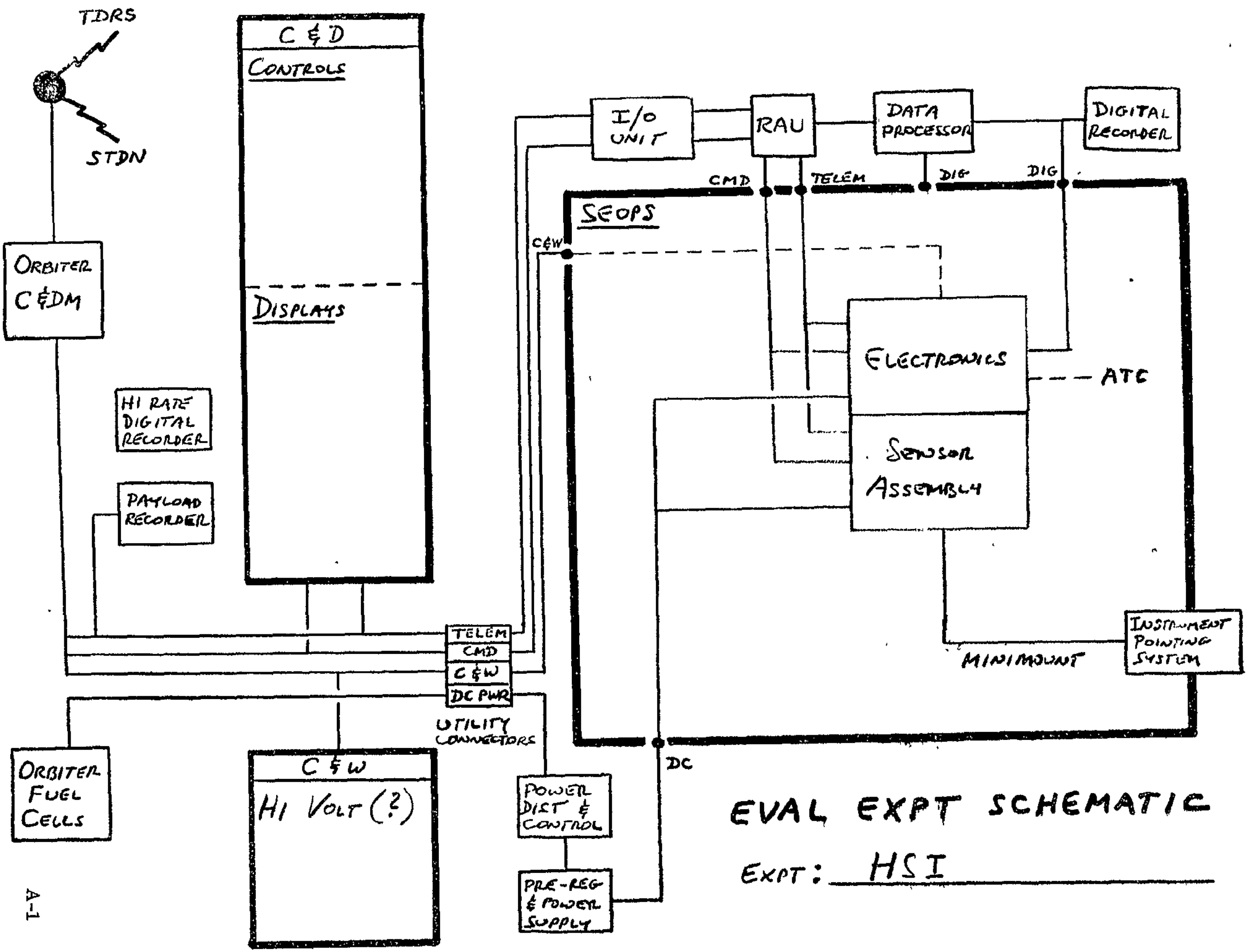
Valley Forge Space Center

P O Box 8555 • Philadelphia, Penna 19101

TABLE OF CONTENTS

APPENDIX A

EXPERIMENT SCHEMATICS



EVAL EXPT SCHEMATIC

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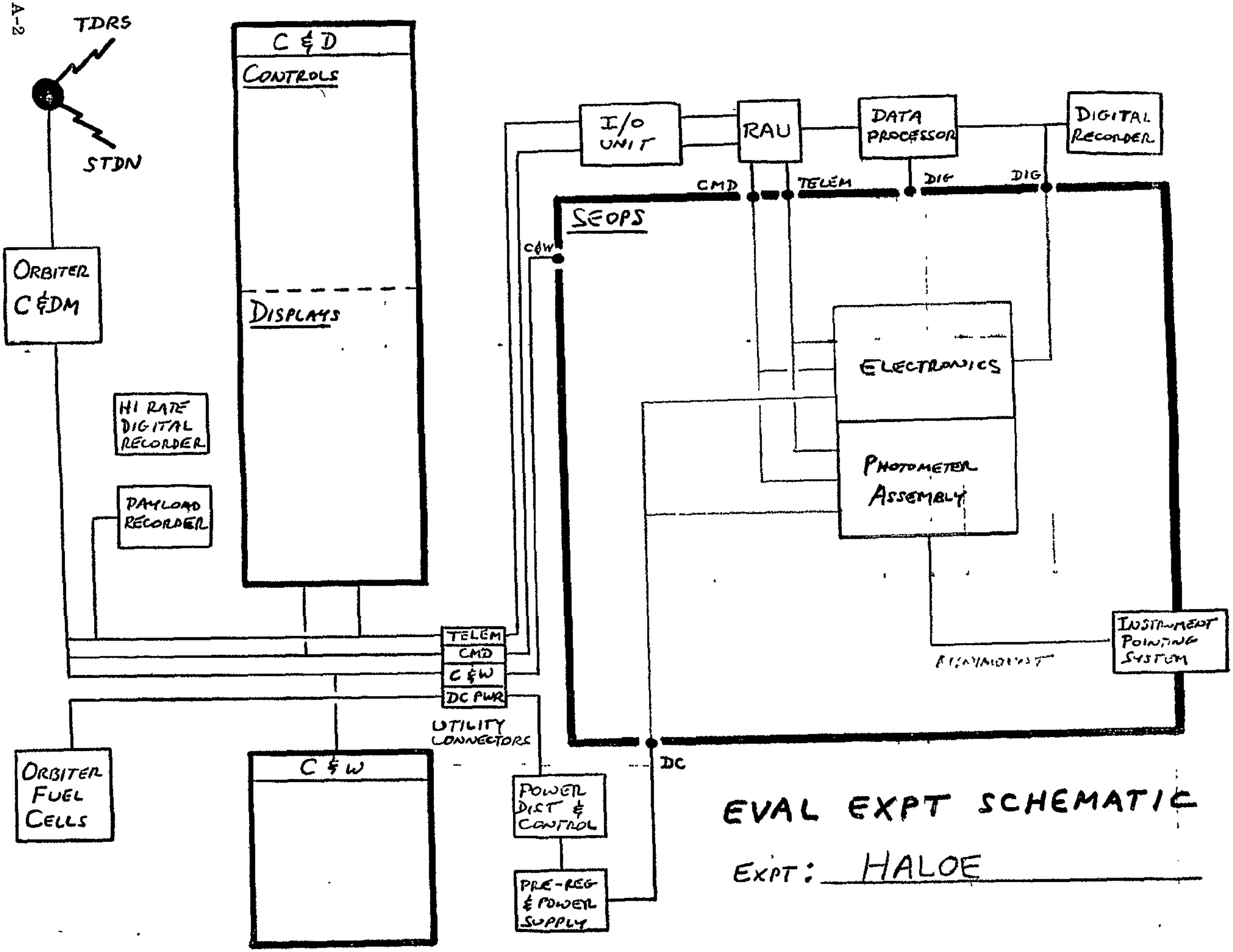

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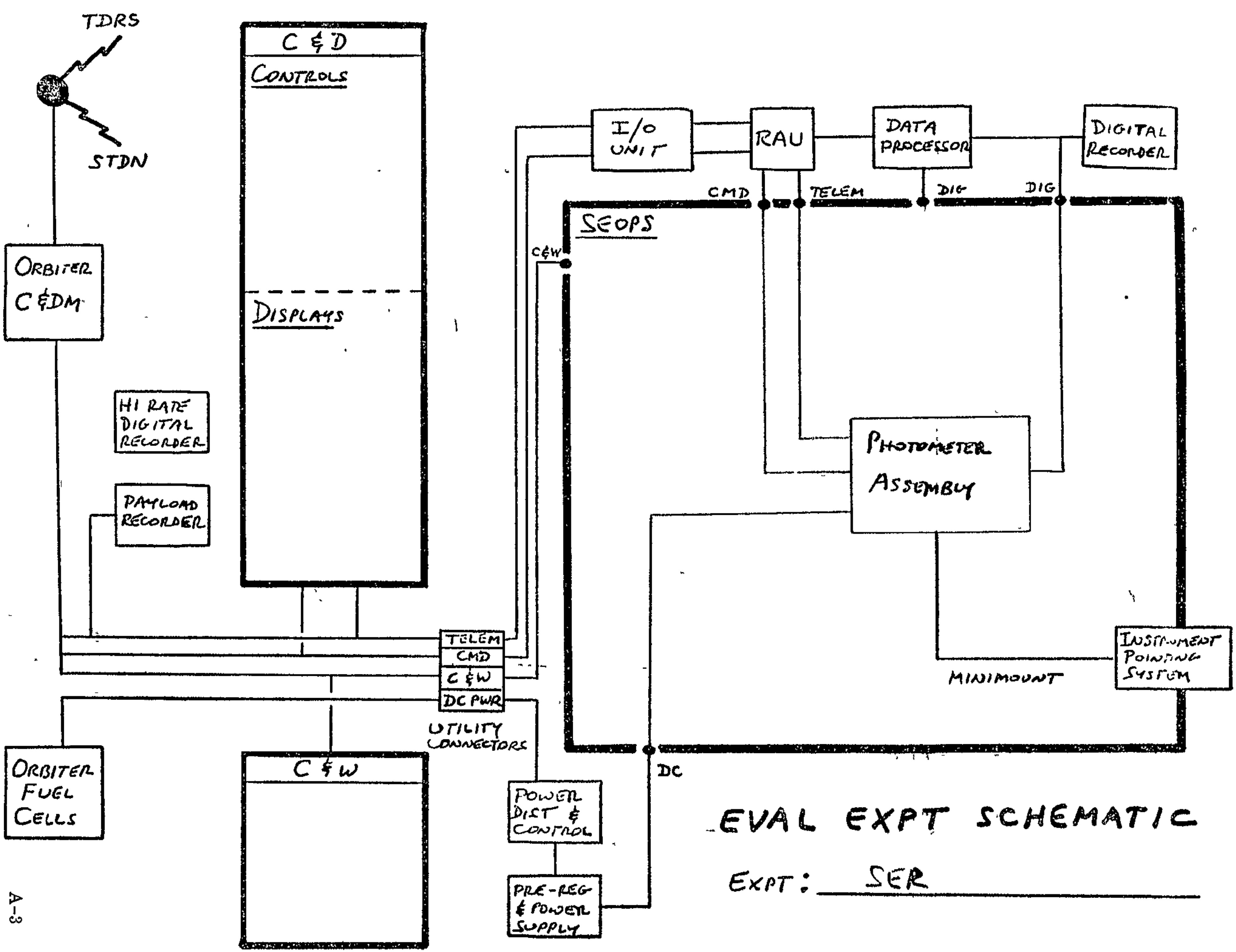
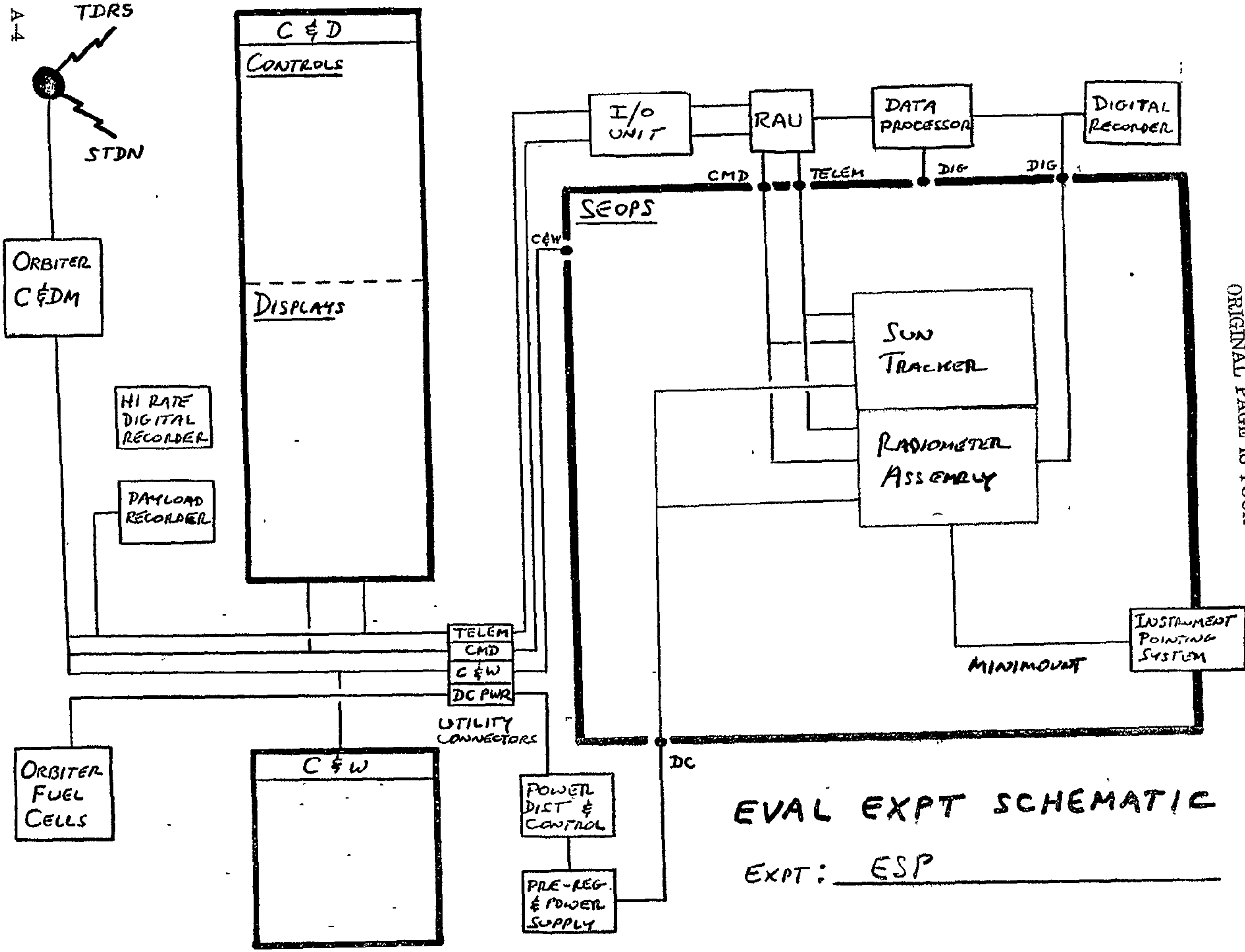

TDRS
STDN
ORBITER C&DM
C & D
CONTROLS
DISPLAYS
HI RATE DIGITAL RECORDER
PAYLOAD RECORDER
TELEM
CMD
C&W
DC PWR
UTILITY CONNECTORS
ORBITER FUEL CELLS
C & W
POWER DIST & CONTROL
PRE-REG & POWER SUPPLY
I/O UNIT
RAU
DATA PROCESSOR
DIGITAL RECORDER
CMD
TELEM
DIG
DIG
SEOPS
C&W
PHOTOMETER ASSEMBLY
INSTRUMENT POINTING SYSTEM
MINIMOUNT
DC
EVAL EXPT SCHEMATIC
EXPT: SER



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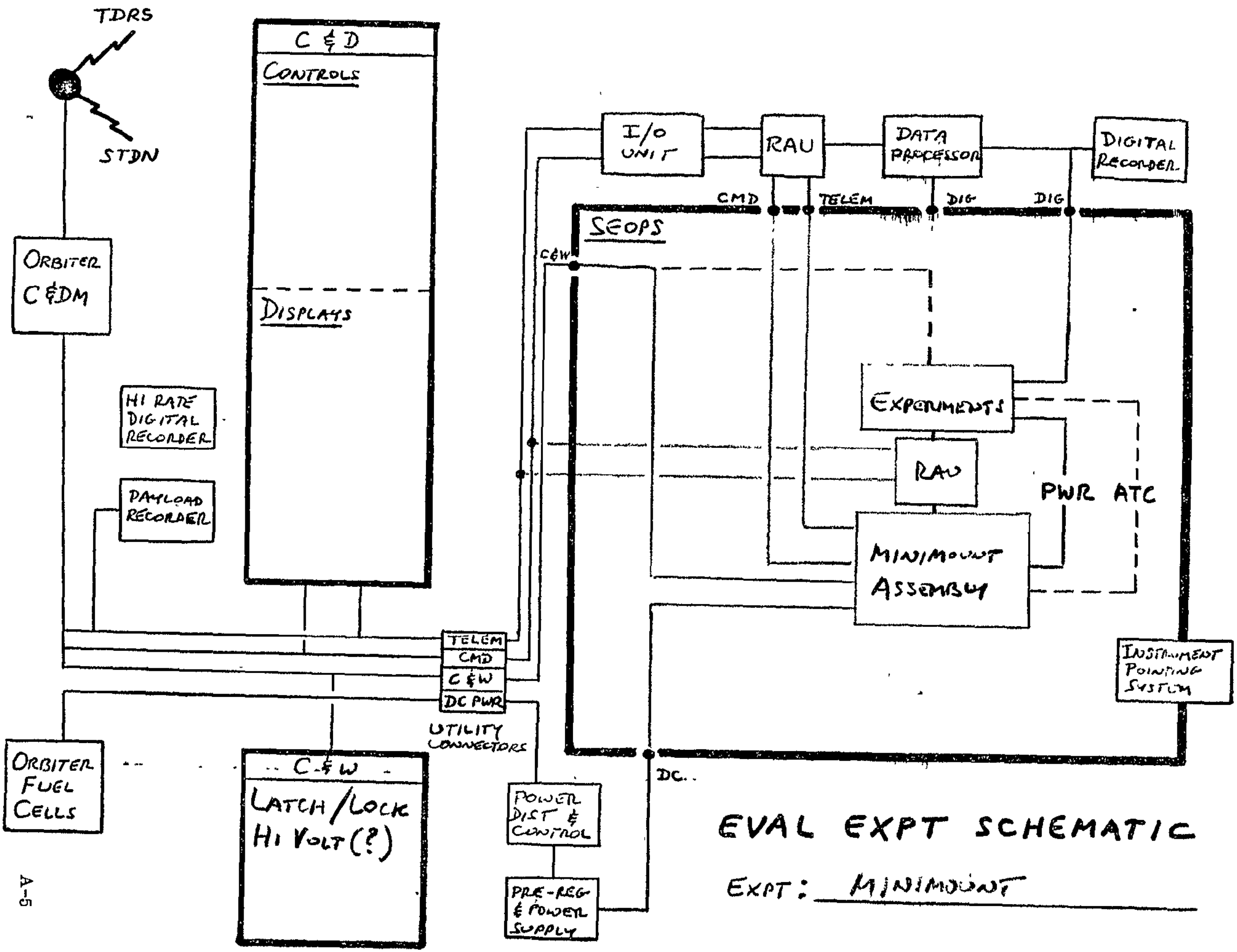
EXPT: ESP



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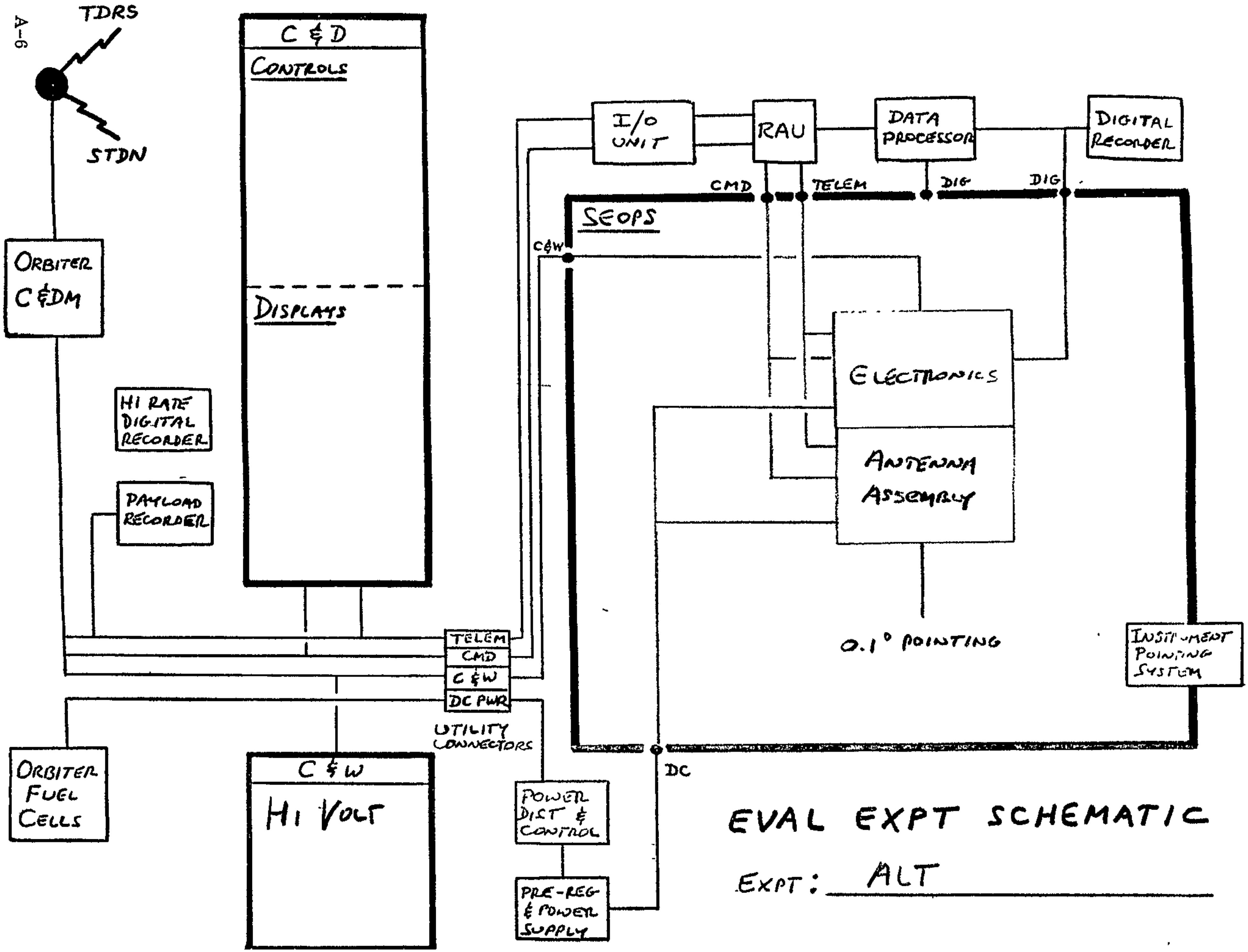
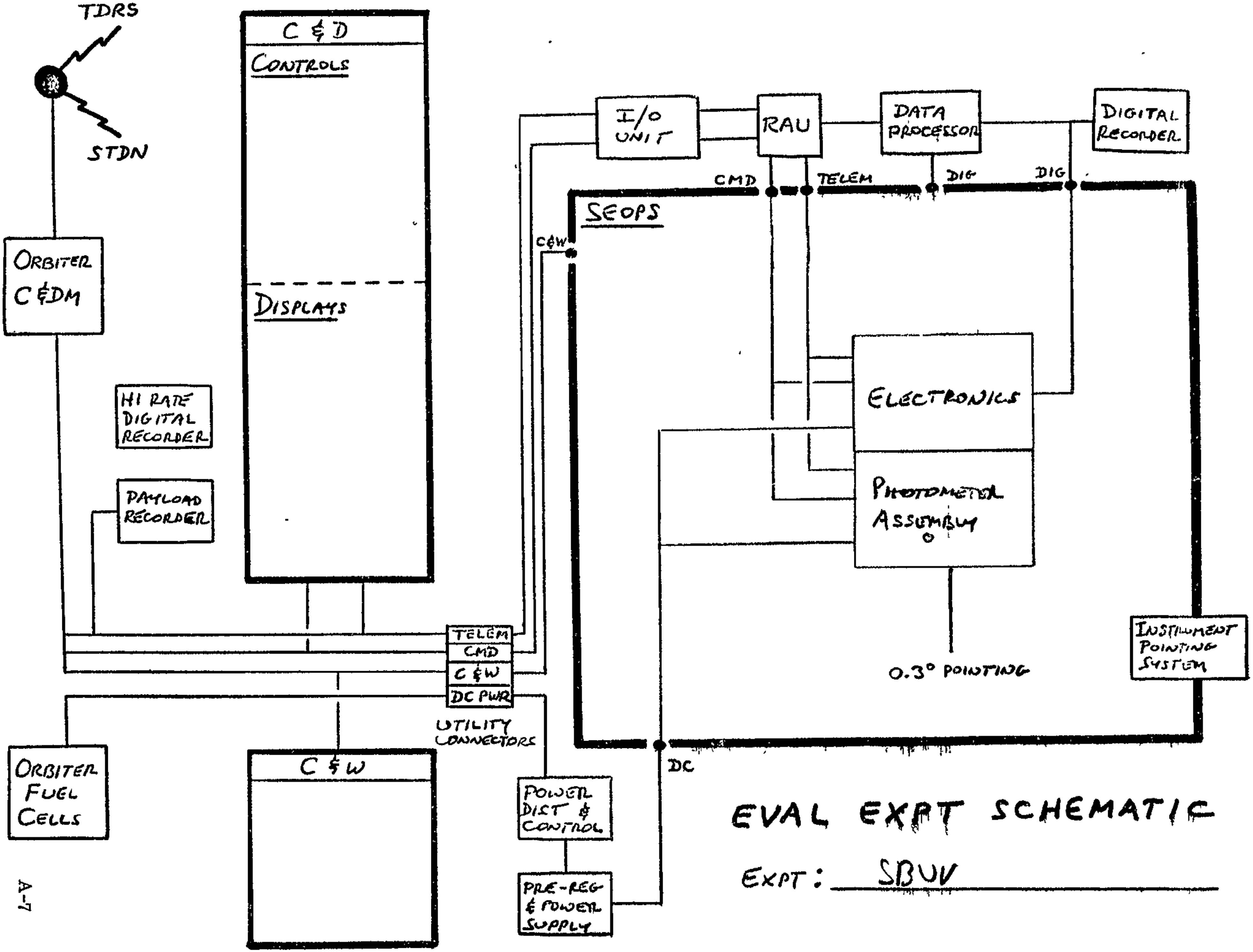
EXPT: MINIMOUNT



EVAL EXPT SCHEMATIC

EXPT: ALT



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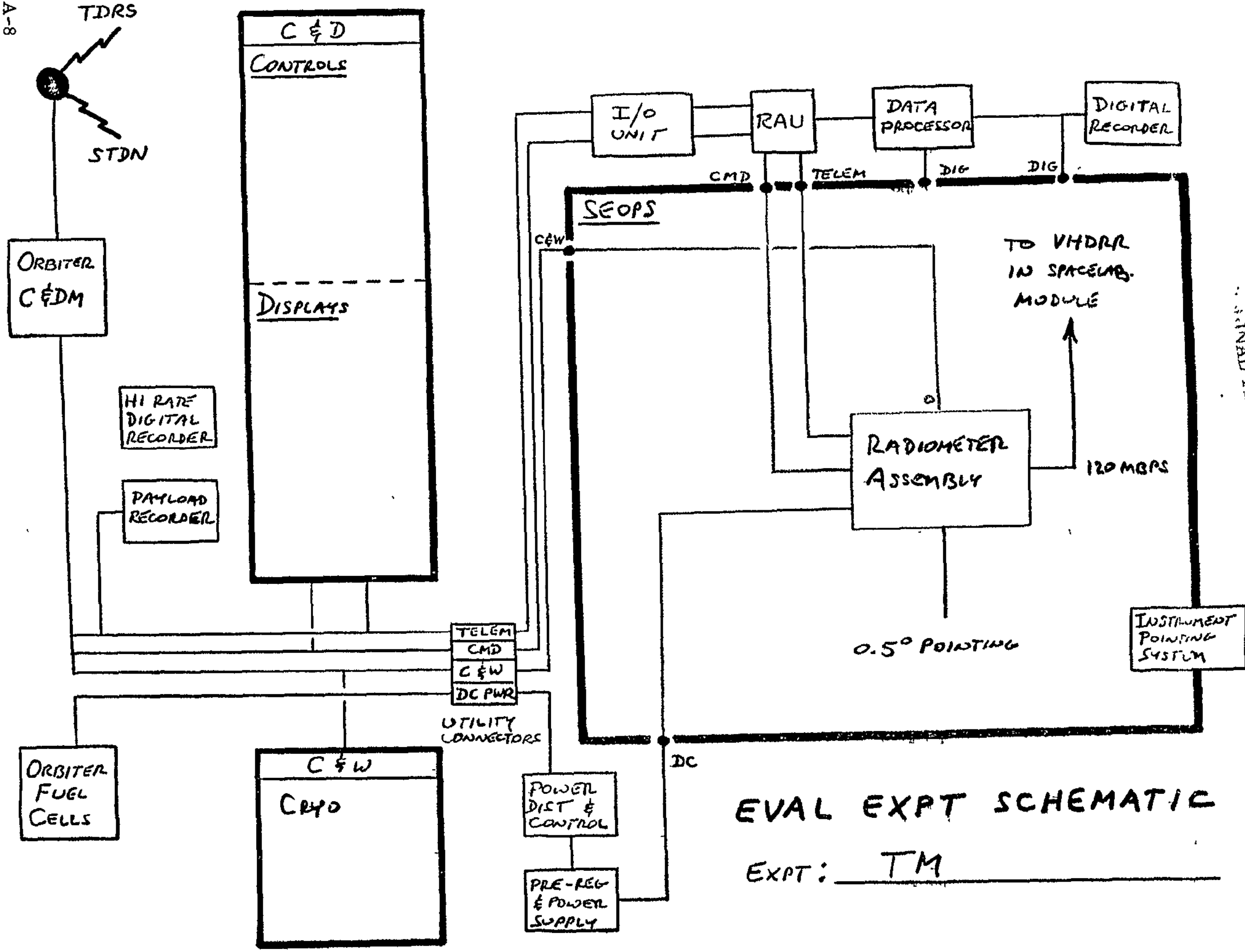

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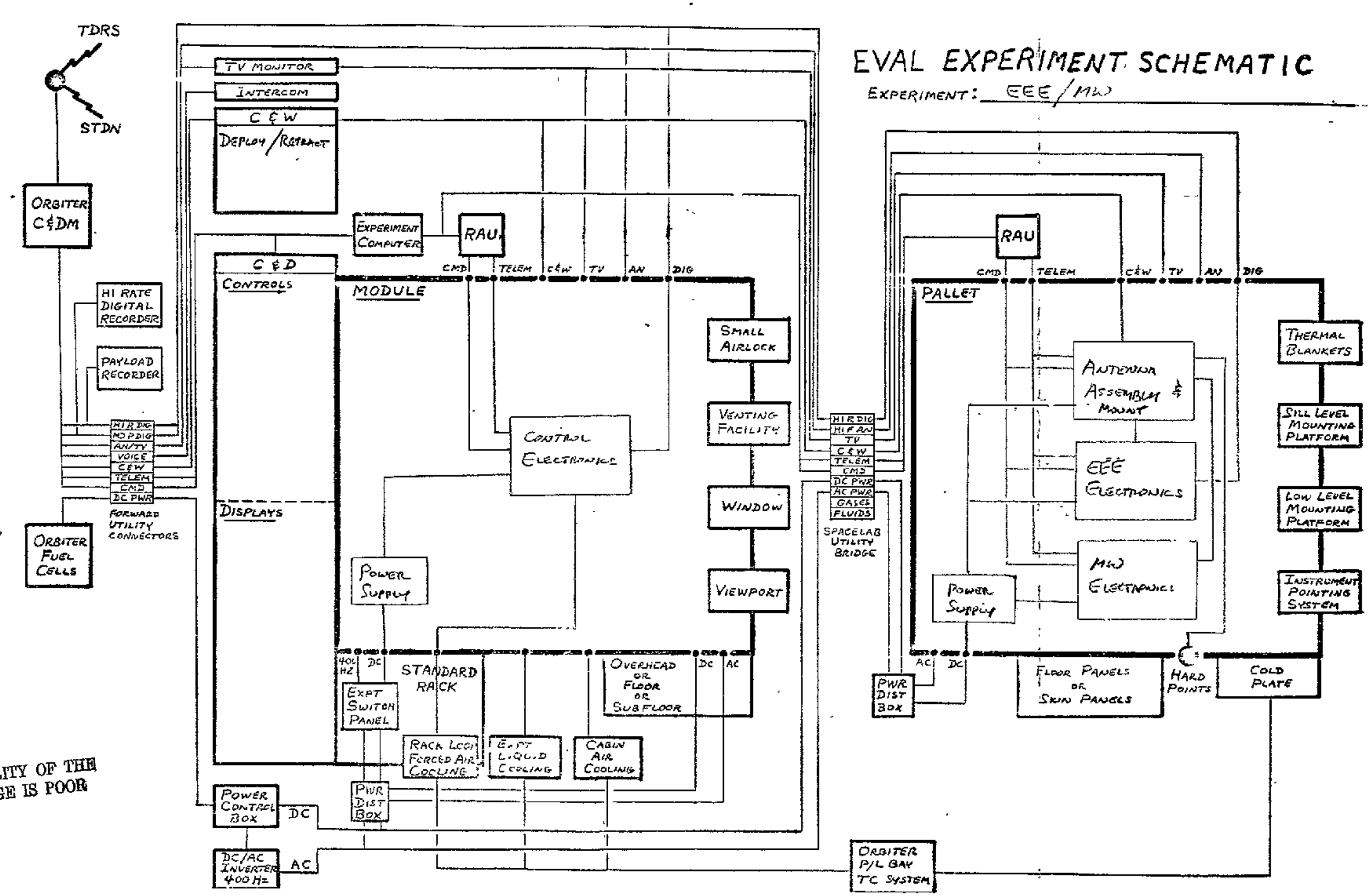
EXPT: TM



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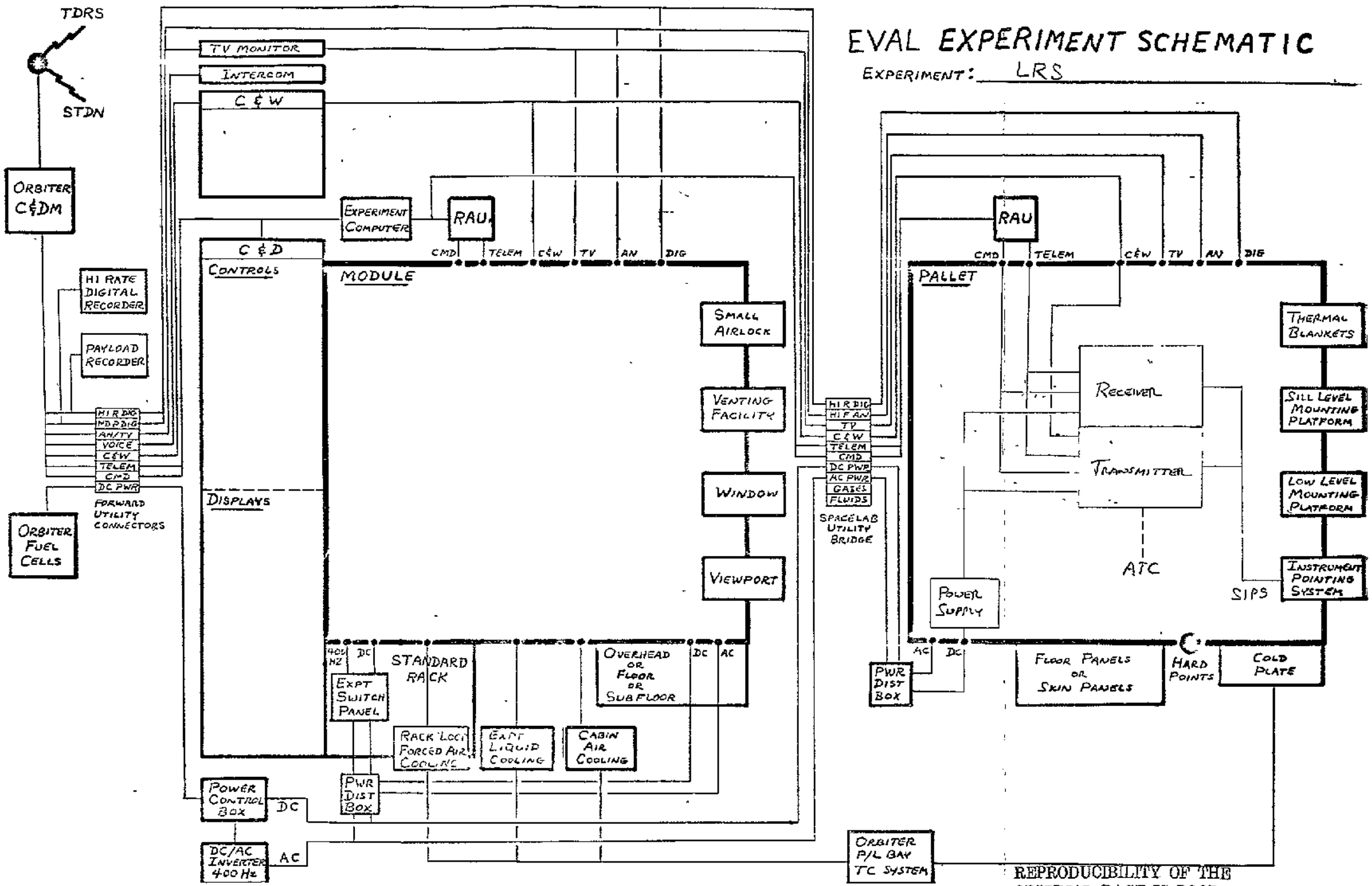
EVAL EXPERIMENT SCHEMATIC

EXPERIMENT: LRS



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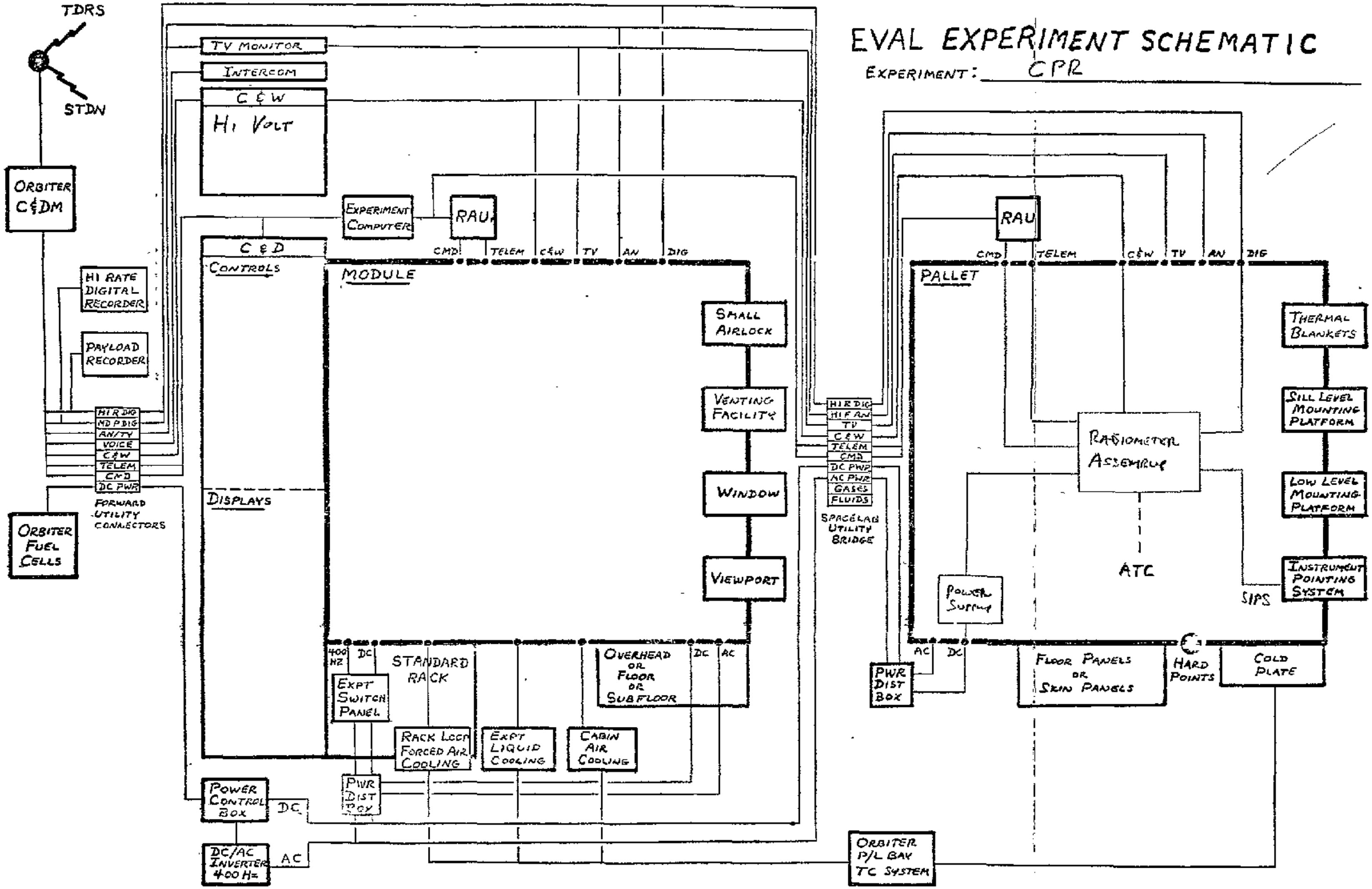
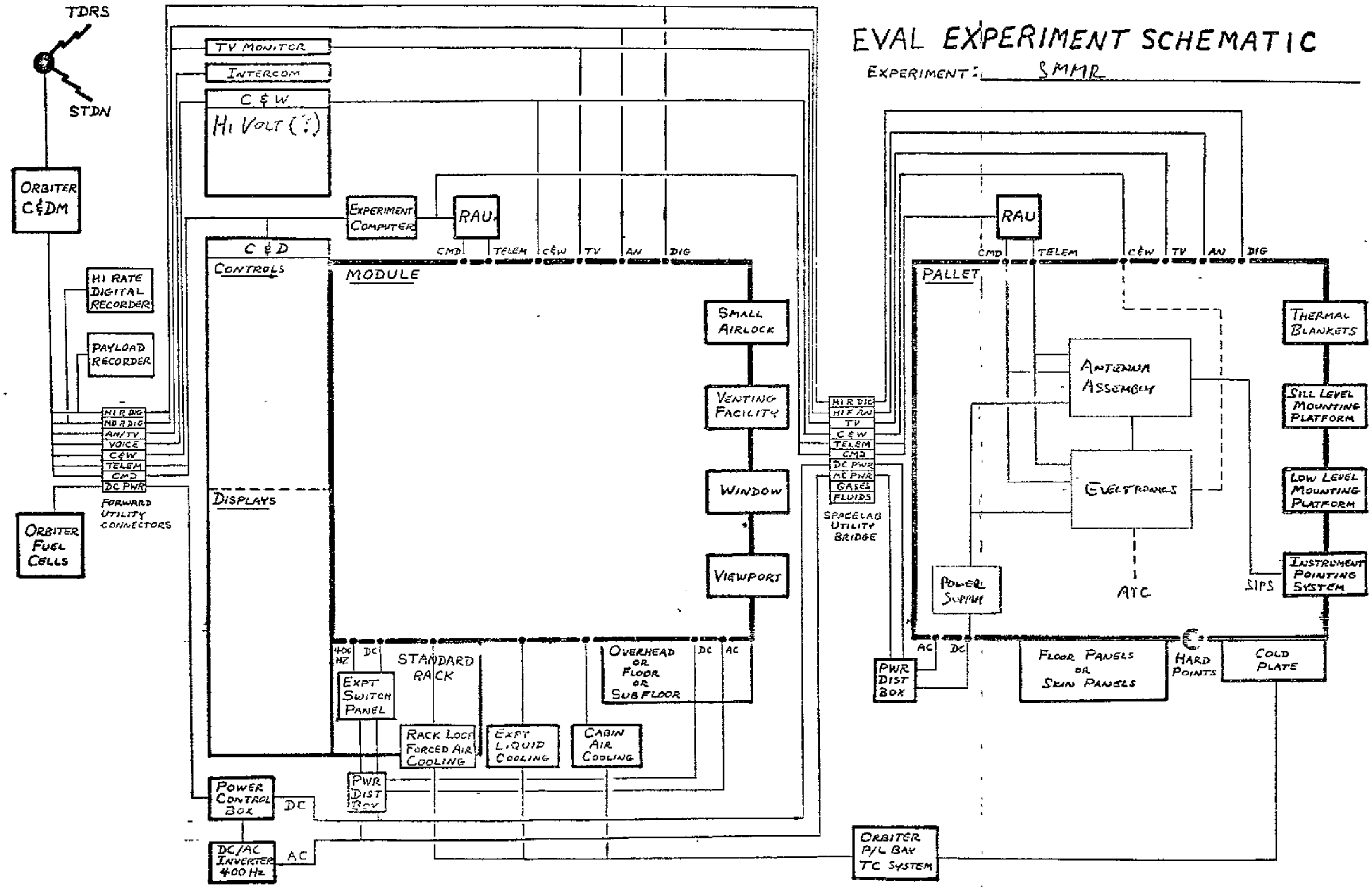


EVAL EXPERIMENT SCHEMATIC
EXPERIMENT: CPR
TDRS
STDN
ORBITER C&DM
HI RATE DIGITAL RECORDER
PAYLOAD RECORDER
HI R DIG
MD P DIG
AN/TV
VOICE
C&W
TELEM
CMD
DC PWR
FORWARD UTILITY CONNECTORS
ORBITER FUEL CELLS
TV MONITOR
INTERCOM
C&W
HI VOLT
EXPERIMENT COMPUTER
RAU
C&D
CONTROLS
DISPLAYS
MODULE
CMD
TELEM
C&W
TV
AN
DIG
SMALL AIRLOCK
VENTING FACILITY
WINDOW
VIEWPORT
400 HZ
DC
STANDARD RACK
EXPT SWITCH PANEL
RACK LOCAL FORCED AIR COOLING
EXPT LIQUID COOLING
CABIN AIR COOLING
OVERHEAD OR FLOOR OR SUBFLOOR
DC
AC
POWER CONTROL BOX
DC
PWR DIST BOX
DC/AC INVERTER 400 Hz
AC
HI R DIG
HI F AN
TV
C&W
TELEM
CMD
DC PWR
AC PWR
GASES
FLUIDS
SPACELAB UTILITY BRIDGE
RAU
PALLET
CMD
TELEM
C&W
TV
AN
DIG
RADIOMETER ASSEMBLY
ATC
POWER SUPPLY
THERMAL BLANKETS
SILL LEVEL MOUNTING PLATFORM
LOW LEVEL MOUNTING PLATFORM
INSTRUMENT POINTING SYSTEM
SIPS
AC
DC
PWR DIST BOX
FLOOR PANELS OR SKIN PANELS
HARD POINTS
COLD PLATE
ORBITER P/L BAY TC SYSTEM

EVAL EXPERIMENT SCHEMATIC

EXPERIMENT: SMMR



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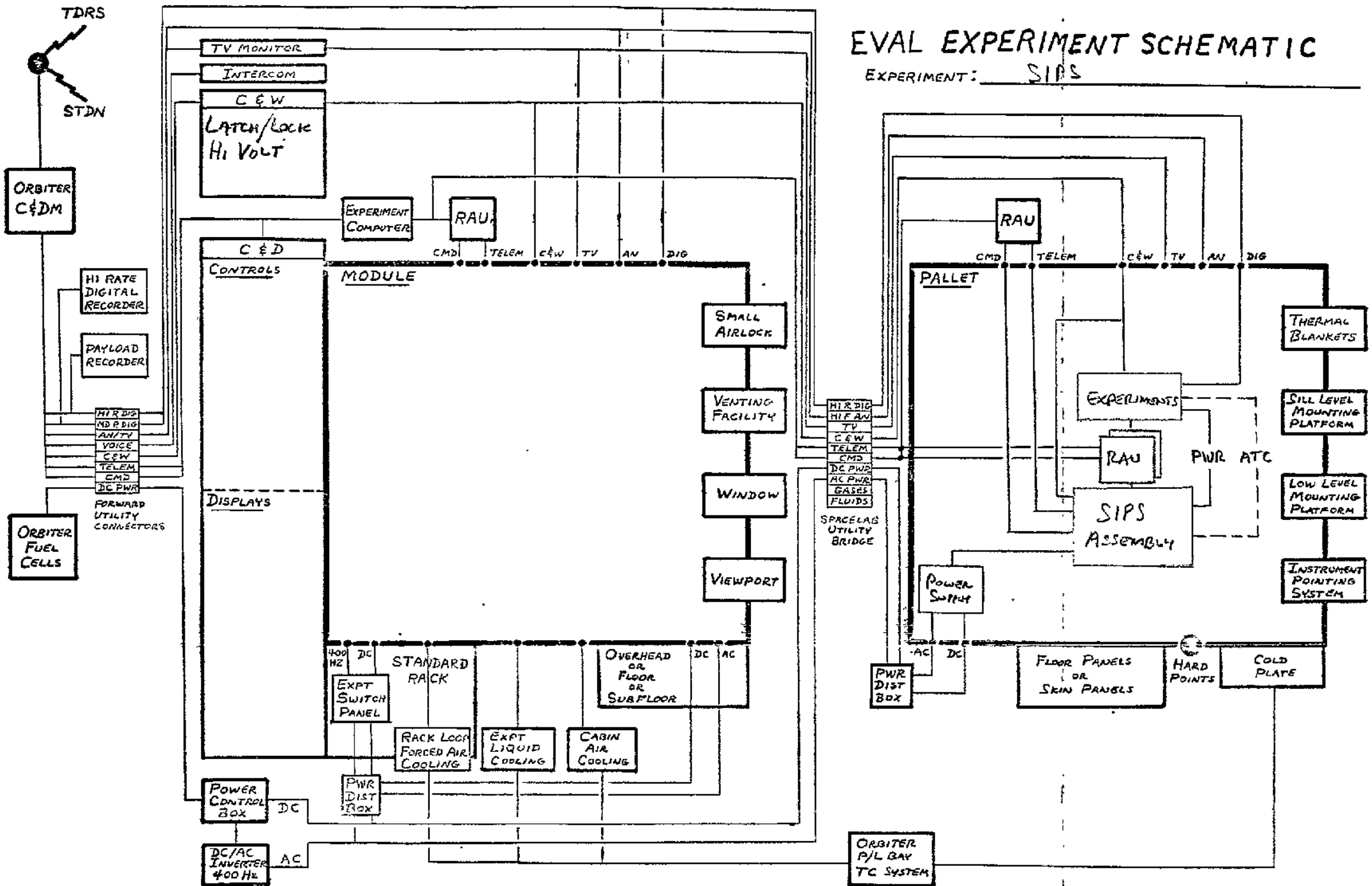
EVAL EXPERIMENT SCHEMATIC

EXPERIMENT: SIPS



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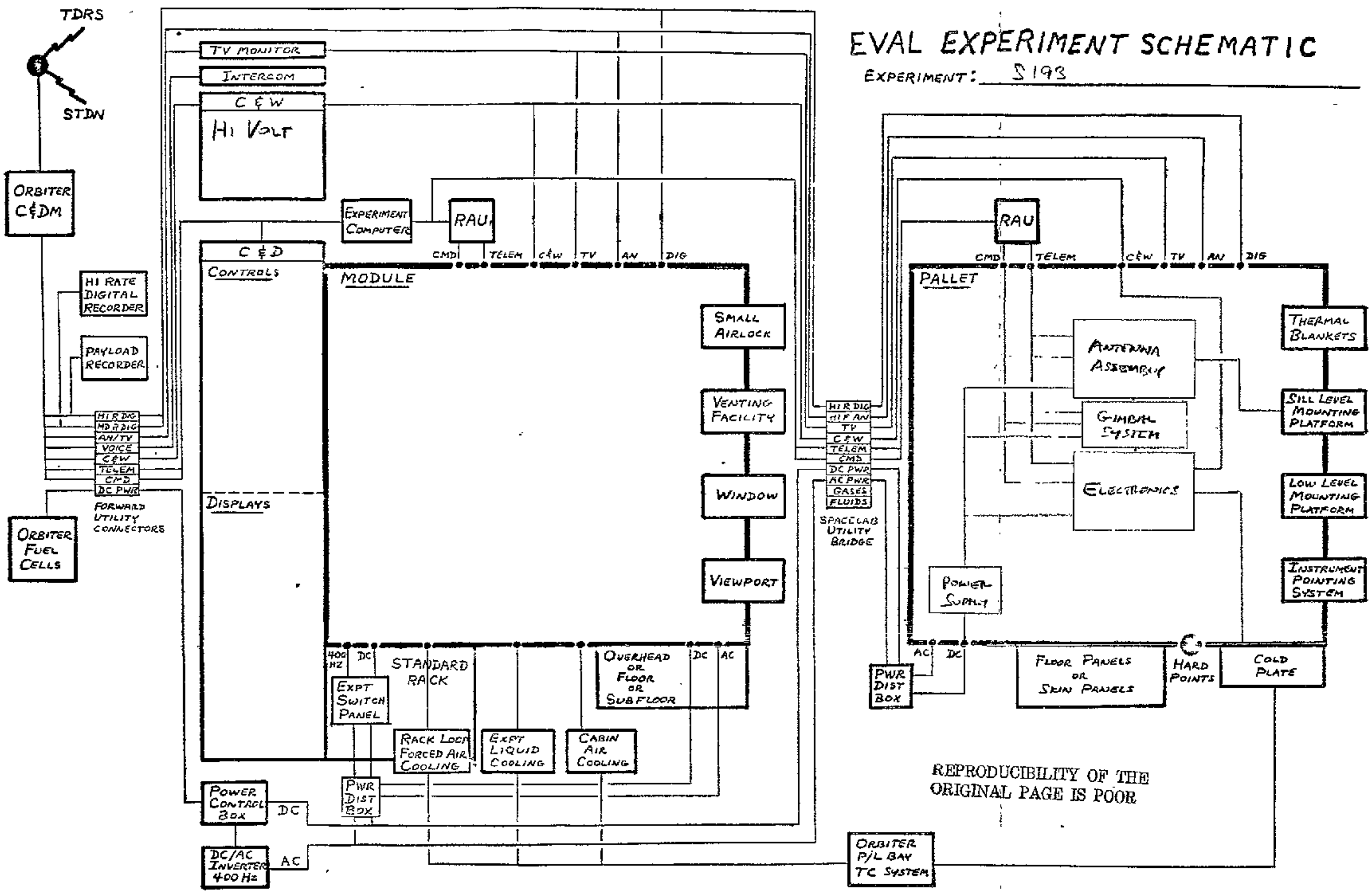
EVAL EXPERIMENT SCHEMATIC

EXPERIMENT: S193



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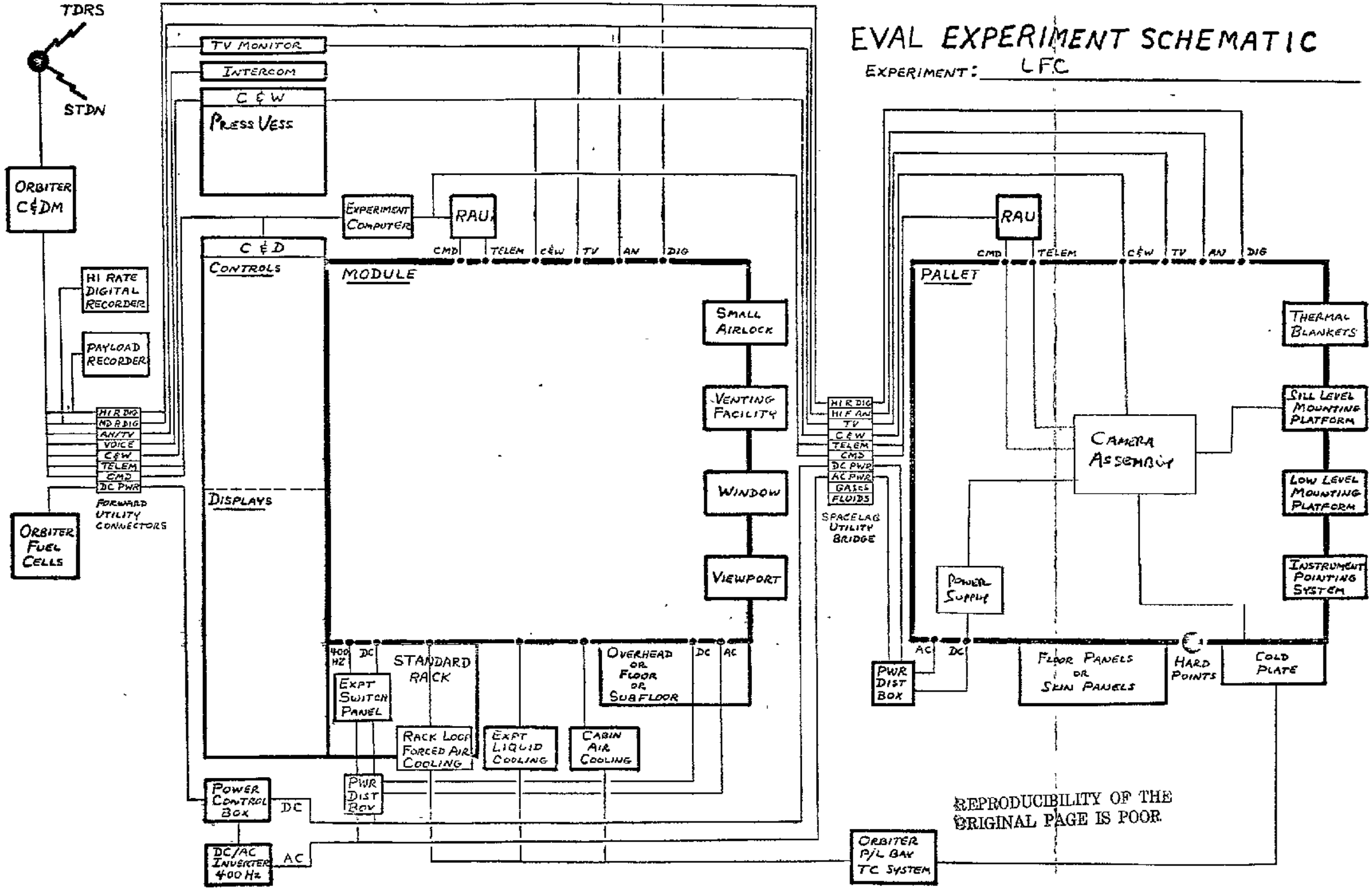
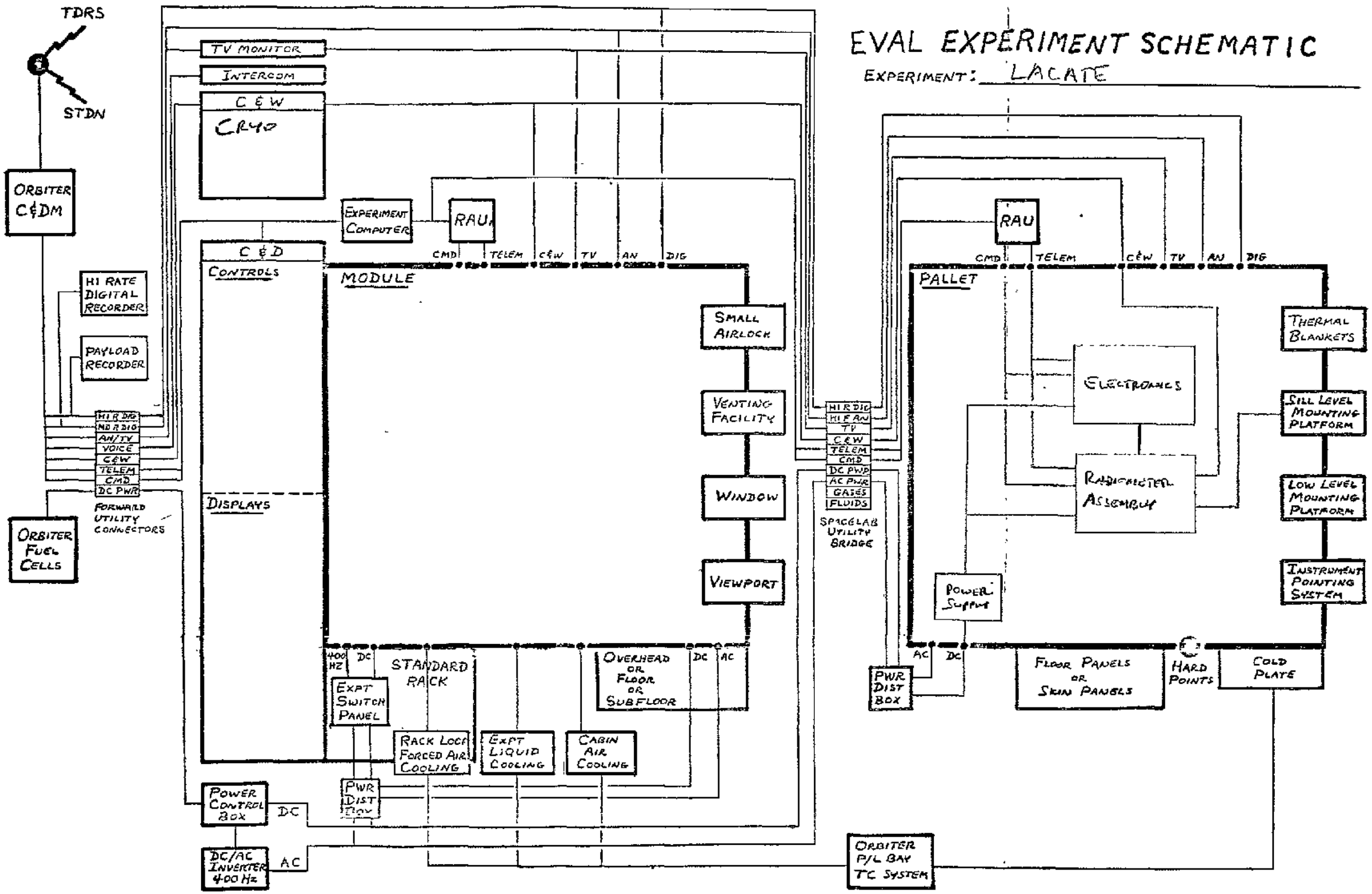
EVAL EXPERIMENT SCHEMATIC

EXPERIMENT: LFC



EVAL EXPERIMENT SCHEMATIC

EXPERIMENT: LACATE



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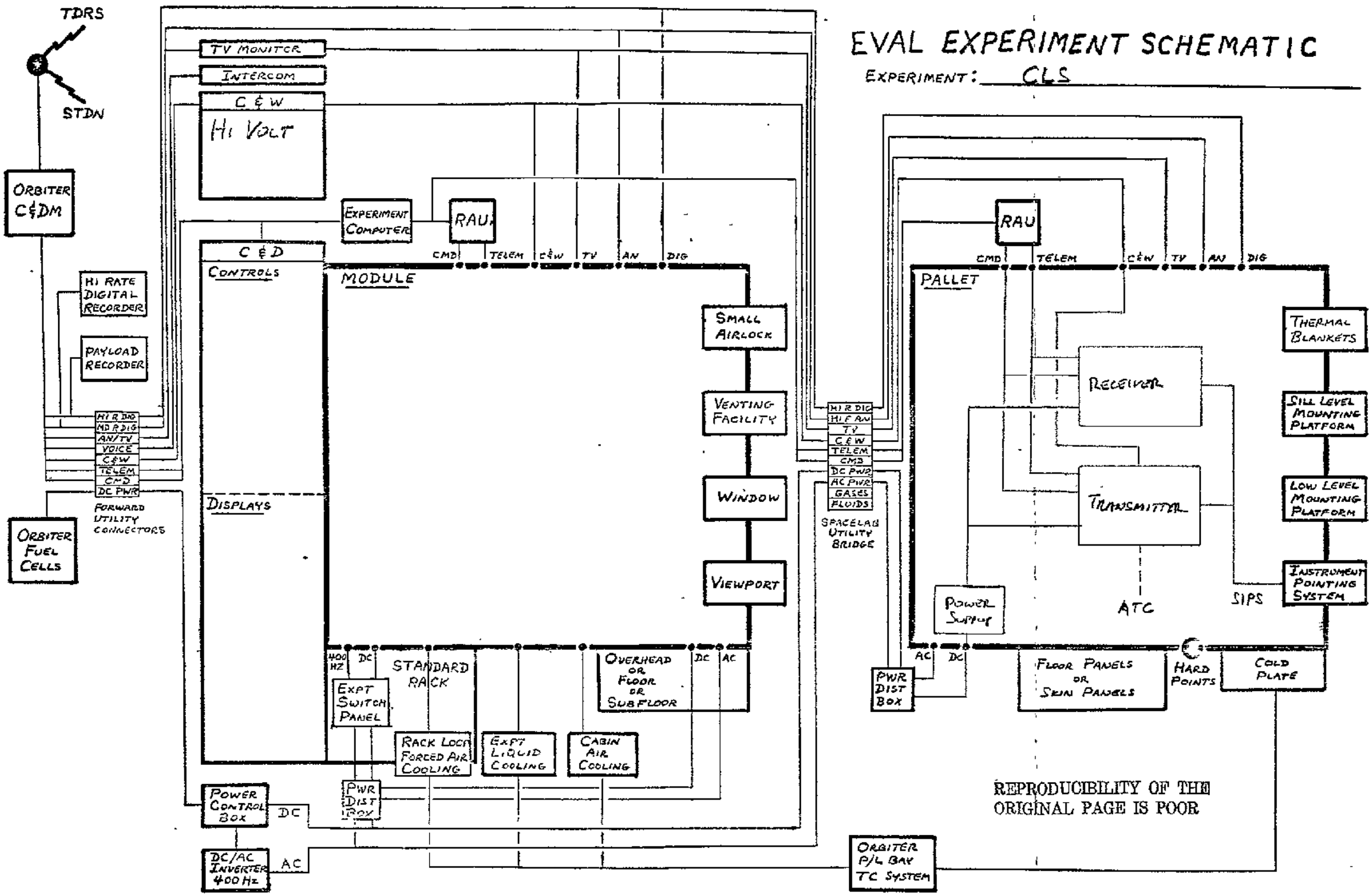
EVAL EXPERIMENT SCHEMATIC

EXPERIMENT: CLS



APPENDIX B

MISSION OPPORTUNITIES

N. ATLANTIC
(WAVES)

Orbit & Target Location	Daylight Pass (min.)	Nighttime Pass (min.)
0C	6.5	
1C	7.0	
2C	8.0	
3FW	4.5	
4NWT		
13 SET		
14SE	4.0	
15C	6.0	
16C	7.5	
17C	8.0	
18SW	8.6	
19FSW	2.5	
29FSE	2.5	
– 30SE	6.5	
– 31C	7.5	
32C	7.5	
33C	9.0	
– 34SW	5.5	
45SET	4.5	
46C	6.5	
47C	8.0	
48C	9.0	
49C	8.5	
50SWT	1.5	
60FSET	2.0	
61SE	5.0	
62C	6.5	
63C	8.0	
64C	10.0	
65SW	6.5	
76SET	3.5	
77C	6.5	
78C	8.0	
79C	8.0	
80C	9.0	
81SW	4.5	
92SET	3.5	1.5
93C	6.5	
94C	8.0	
– 95C	10.0	
– 96C	8.0	

LEGEND

13 GSET

GSET → Geographic sectior

13 → Orbit number

N - North

S - South

E - East

W - West

C - Central

NE - North East

SW - South West

SET - South East Tip

FNW - Far North West

GSET - Graze South East Tip

Etc.

– Indicates orbits which were selected for data taking operations

N. PACIFIC
(WAVES)

Orbit & Target Location	Daylight Pass (min.)	Nighttime Pass (min.)
3FE	1.5	
4E	5.0	
5E	8.0	
6C	12.0	
7C	11.0	
8C	9.0	
9WT	2.5	
19SE	3.5	
20E	6.5	
21C	21.0	
22C	13.5	
23C	13.0	
24C	6.0	
25SW	3.0	
26GSW	0.5	
34SET	1.5	
35SE	4.5	
36C	7.5	
37C	11.5	
38C	13.0	
39C	8.5	
40SW	5.5	
41 SWT	3.5	
50SET	6.0	
51SE	6.5	
52C	8.5	
53C	13.5	
54C	11.0	
55C	7.5	
56SW	4.5	
57FSWT	2.5	
66SE	4.0	
67E	7.5	
68C	10.5	
69C	13.5	
70C	10.0	
71SW	6.5	
72SW	3.5	
81SET	2.0	
82SE	5.5	
83C	8.5	
84C	12.0	
85C	11.5	
86C	7.5	
87SW	5.0	
88SWT	3.0	
97SET	2.5	1.5
98E	4.5	1.5
99C	8.0	2.0

Orbit & Target Location	Daylight Pass (min.)	Nighttime Pass (min.)
100C	12.5	1.5
101C	5.5	
102SW	6.5	
103SW	4.5	
104SWT	0.5	

GULF STREAM
(CURRENT)

Orbit & Target Location	Daylight Pass (min.)	Nightime Pass (min.)
21C	1.5	
31E		4.5
52N	1.5	
68S	1.5	
78W		2.5
99C	2.0	

SEA OF JAPAN
(CURRENT)

Orbit & Target Location	Daylight Pass (min.)	Nightime Pass (min.)
7G	4.0	
11NE	1.5	
12GSW	1.5	
22GE	3.5	
27C	3.5	
38C	4.5	
42NET	2.5	
43SWT	1.0	
58C	3.0	
69E		4.5
73GN	1.5	
74C	3.0	
85GW	1.5	2.5
89N	3.0	
100GE		3.0
105C	3.0	

NEWFOUNDLAND BANKS
(TEMP)

Orbit & Target Location	Daylight Pass (min.)	Nightime Pass (min.)
4G	2.0	
15E	3.0	
19NE	2.5	
31GW	2.0	
35W	2.0	
46G	2.0	
50GNE	2.0	
62C	3.0	
66C	2.5	
93E		3.0
97NE	2.5	

SPANISH SAHARA COASTAL WATERS
(TEMP)

Orbit & Target Loaction	Daylight Pass (min.)	Nightime Pass (min.)
3C	2.0	
13GW	3.0	
19G	2.0	
34NET	2.0	
44C		4.0
50SW	3.0	
75E	2.0	
81C	3.5	
91GW		4.0
97G	2.0	

PERU COASTAL WATERS
(TEMP)

Orbit & Target Location	Daylight Pass (min.)	Nightime Pass (min.)
7G	1.5	
8W	4.5	
14SE		1.0
15GNW		2.5
30C		4.0
39C	7.5	
46N		3.5
61SE		2.5
70E	6.0	
77C		4.5
86FW	6.0	
92S		2.0
93GNWT		2.5

CONUS
(EM)

Orbit & Target Location	Daylight Pass (min.)	Nightime Pass (min.)
16E	8.0	
17C	7.5	
18NW	3.5	
33W	7.0	
48C	5.0	3.0
49NW	6.0	
54GFW	2.5	
64SW	3.5	4.0
65NWT	3.5	
78SE	1.0	4.0
79C	1.5	7.0
80SW	3.0	4.0

CONUS
(MW)

Orbit & Target Location	Daylight Pass (min.)	Nightime Pass (min.)
5FE	2.0	
— 16E	2.5	
— 21E	3.0	
— 32C	1.0	
36FNE	2.0	
47SE	2.0	1.0
52NE	3.0	
— 63E		2.0
83NE	2.5	
— 94E		2.5
— 99C	3.0	

CHILE
(MINERAL)

Orbit & Target Location	Daylight Pass (min.)	Nightime Pass (min.)
23N	2.5	
45N		2.5
70N	2.5	
76N		3.5
101GN	2.0	

PERU
(MINERAL)

Orbit & Target Location	Daylight Pass (min.)	Nightime Pass (min.)
14S		3.5
23C	3.5	
30C		3.0
54NET	5.5	
61C		3.5
70W	6.0	
77FW		2.0
92S		2.0
101C	6.0	

ZAIRE
(MINERAL)

Orbit & Target Location	Daylight Pass (min.)	Nightime Pass (min.)
3C	2.0	
10E		5.0
19FW	3.0	
26W		5.5
33E	4.0	
41SET		3.0
50W	5.0	
57C		5.5
64NET	4.0	
66GW	3.0	
73GW		4.5
80C	6.0	
88C		6.0
97FW	3.0	
104W		6.0

ZAMBIA
(MINERAL)

Orbit & Target Location	Daylight Pass (min.)	Nightime Pass (min.)
3C	1.0	
10GW		2.0
19FWG	2.5	
25GE		2.5
33GE	2.0	
41C		3.5
50W	2.0	
72E		4.5
80C	1.5	
97FW	3.0	
103GE		3.0

CONUS
(MINERAL)

Orbit & Target Location	Daylight Pass (min.)	Nightime Pass (min.)
17C	3.5	
22W	5.0	
33W	4.0	
38W	4.0	
48C	5.0	3.0
53W	3.0	
54GFW	2.5	
64SW	3.5	4.0
69W	5.0	
80SW	3.0	4.0
85SW	4.5	6.5
95SW	2.0	
100NW	5.0	

CONUS
(TIMBER)

Orbit & Target Location	Daylight Pass (min.)	Nighttime Pass (min.)
1C	11.0	
2W	6.0	
5FE	4.5	
6C	7.5	
7FW	3.5	
16E	8.0	
17C	7.5	
18NW	3.5	
20FNE	1.5	
21E	7.0	
22W	8.5	
82C	6.0	1.5
33W	7.0	
34W	1.0	
36FNE	2.5	
37C	9.5	
38W	4.5	
47SE	4.5	3.0
48C	5.0	3.0
49NW	6.0	
51 GNET	2.5	
52NE	6.0	
53W	7.5	
63E	2.5	6.0
64SW	3.5	4.0
65NWT	3.5	
67FNE	2.5	
68C	8.5	
69W	7.5	
78SE	1.0	1.0
79C	1.5	7.0
80SW	3.0	4.0
83NE	5.5	
84NW	9.0	
85SW	4.5	
94E		8.5
95SW	2.0	6.5
96NWT	1.5	3.0
98FNE	2.0	
99C	7.5	
100NW	9.0	

CONUS
(URBAN)

Orbit & Target Location	Daylight Pass (min.)	Nightime Pass (min.)
1C	11.0	
2W	6.0	
5FE	4.5	
6C	7.5	
7FW	3.5	
16E	9.0	
17C	7.5	
18NW	3.5	
20FNE	1.5	
21E	1.0	
22W	8.5	
32C	6.0	1.5
33W	7.0	
34NWT	1.0	
36FNE	2.5	
37C	9.5	
38W	4.5	
49SE	3.5	3.0
48C	5.0	3.0
49NW	6.0	
51GNET	2.5	
52NE	6.0	
53W	7.5	
54GSW	2.5	
63E	2.5	6.0
64SW	3.5	4.0
65NWT	3.5	
67FNE	2.5	
68C	8.5	
69W	7.5	
78SE	1.0	1.0
79C	1.5	7.0
80SW	3.0	4.0
83NE	5.5	
84NW	9.0	
85SW	4.5	
94E		8.5
95SW	2.0	6.5
96NWT	1.5	3.0
98FNE	2.0	
99C	7.5	
100NW	9.0	4.0

HAWAII
(URBAN)

Orbit & Target Location	Daylight Pass (min.)	Nighttime Pass (min.)
3C	0.5	0.5
9G	2.0	
34GE		2.0
56C	2.0	
81G		2.0
103GW	2.0	

APPENDIX C

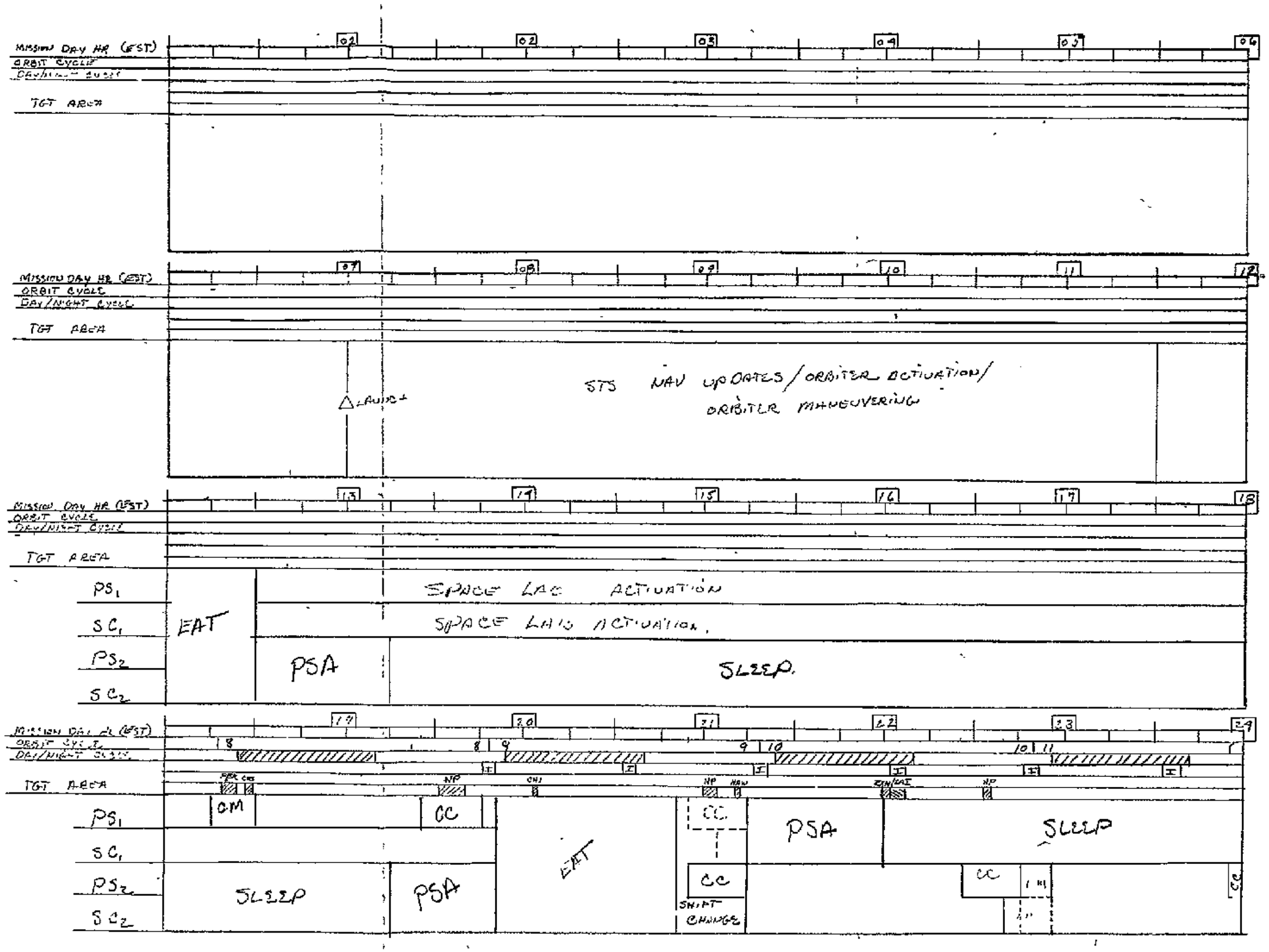
MISSION TIMELINES

APPENDIX D

CREW TIMELINE

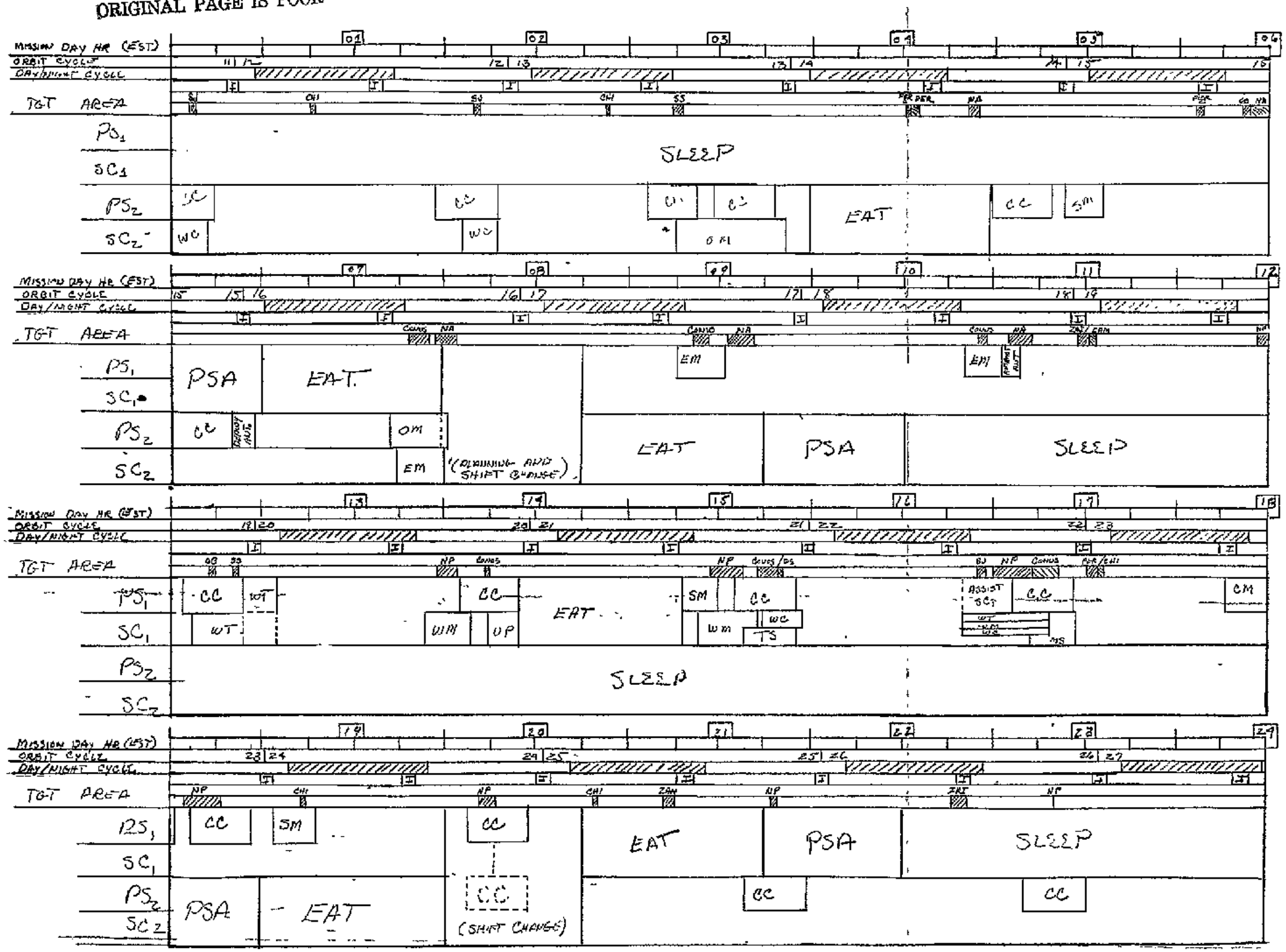
LAUNCH DATE
TIME
INCLINATION
ECCENTRICITY
PERIOD

MISSION DAY 0



LAUNCH DATE
TIME
INCLINATION
ECCENTRICITY
PERIOD

MISSION DAY 1



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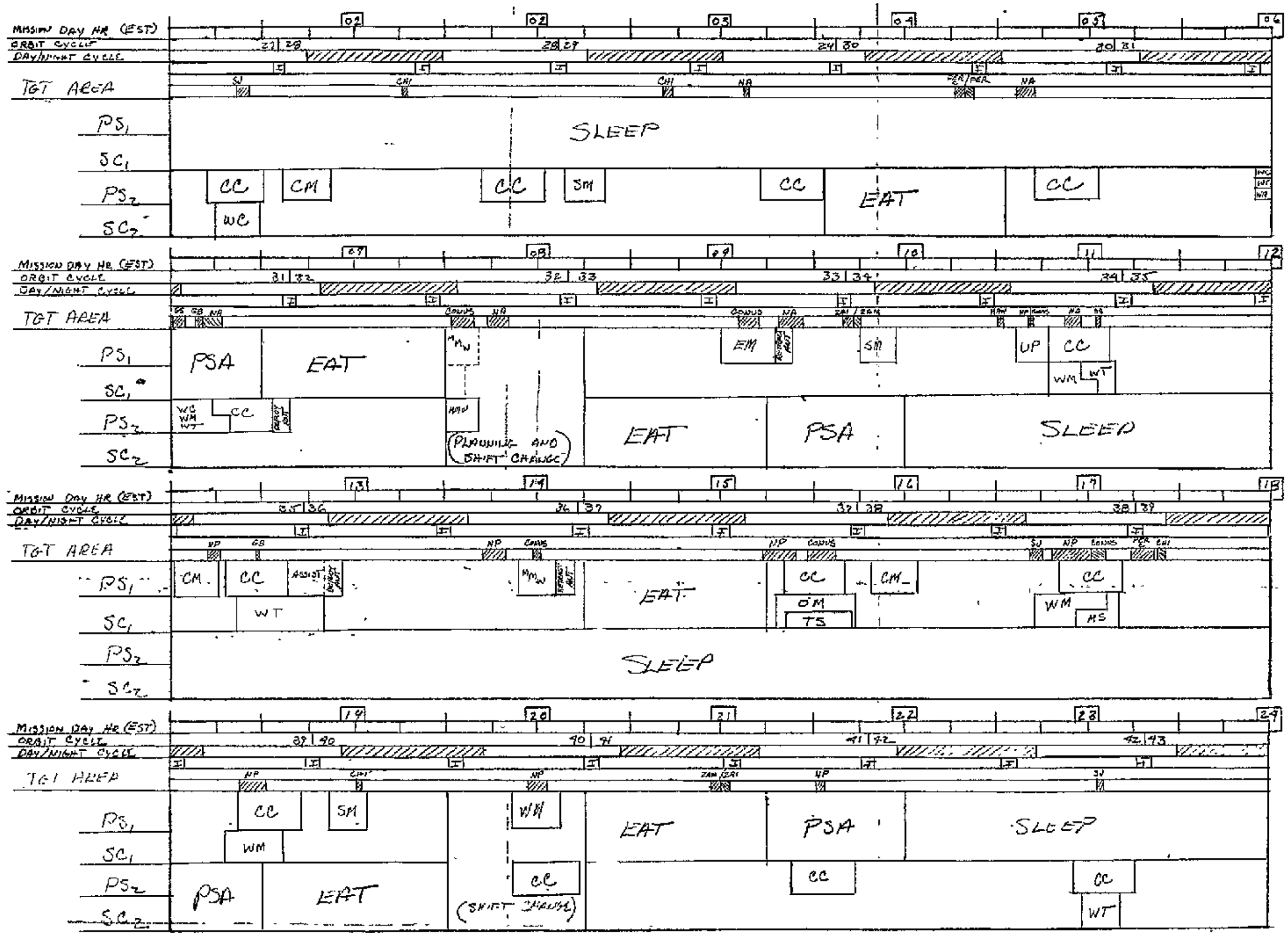
LAUNCH DATE ____
TIME ____
INCLINATION ____
ECCENTRICITY ____
PERIOD ____

MISSION DAY 2



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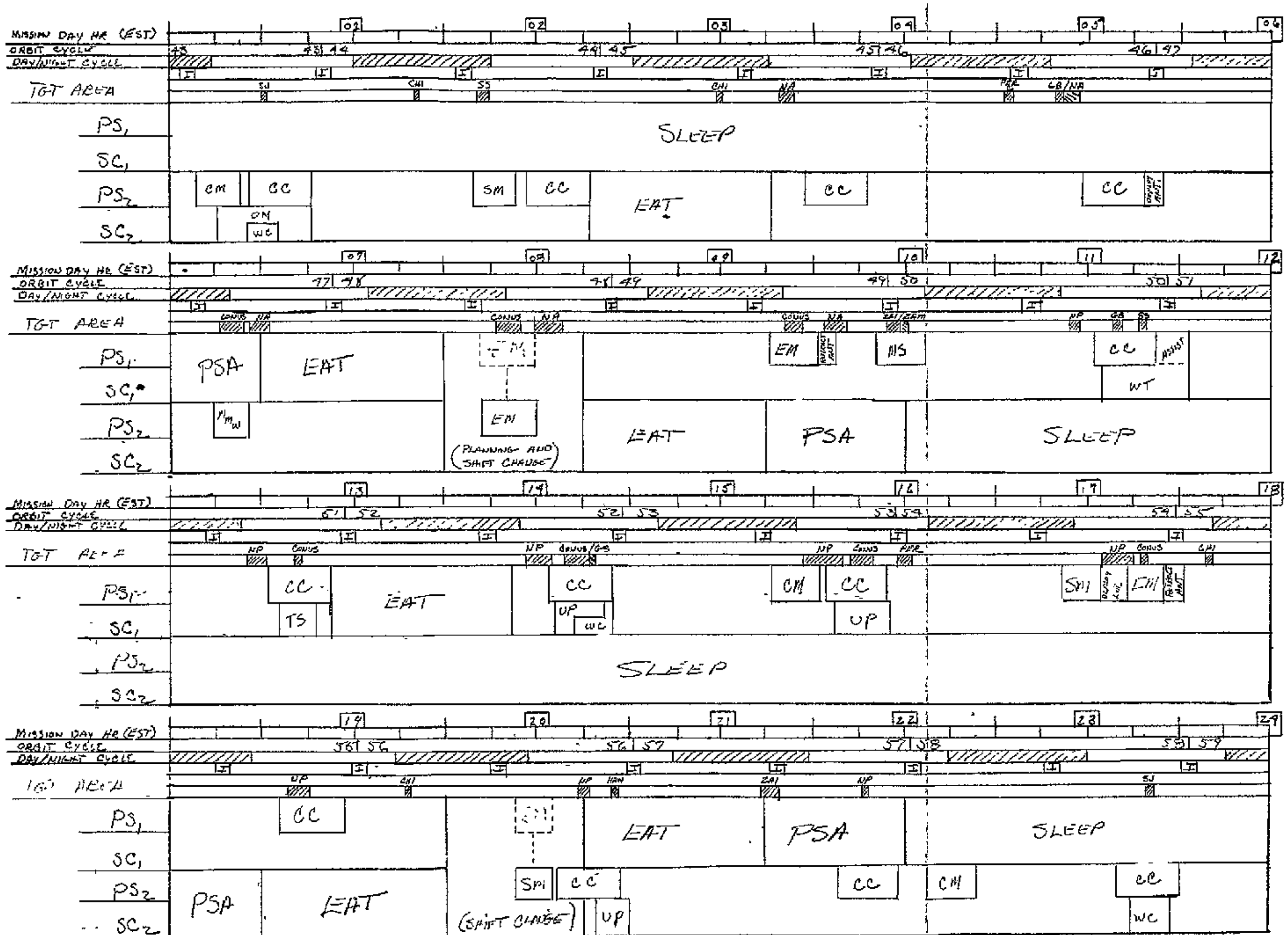
FOLDOUT FRAME 2

LAUNCH DATE ____
TIME ____
INCLINATION ____
ECCENTRICITY ____
PERIOD ____

MISSION DAY 3



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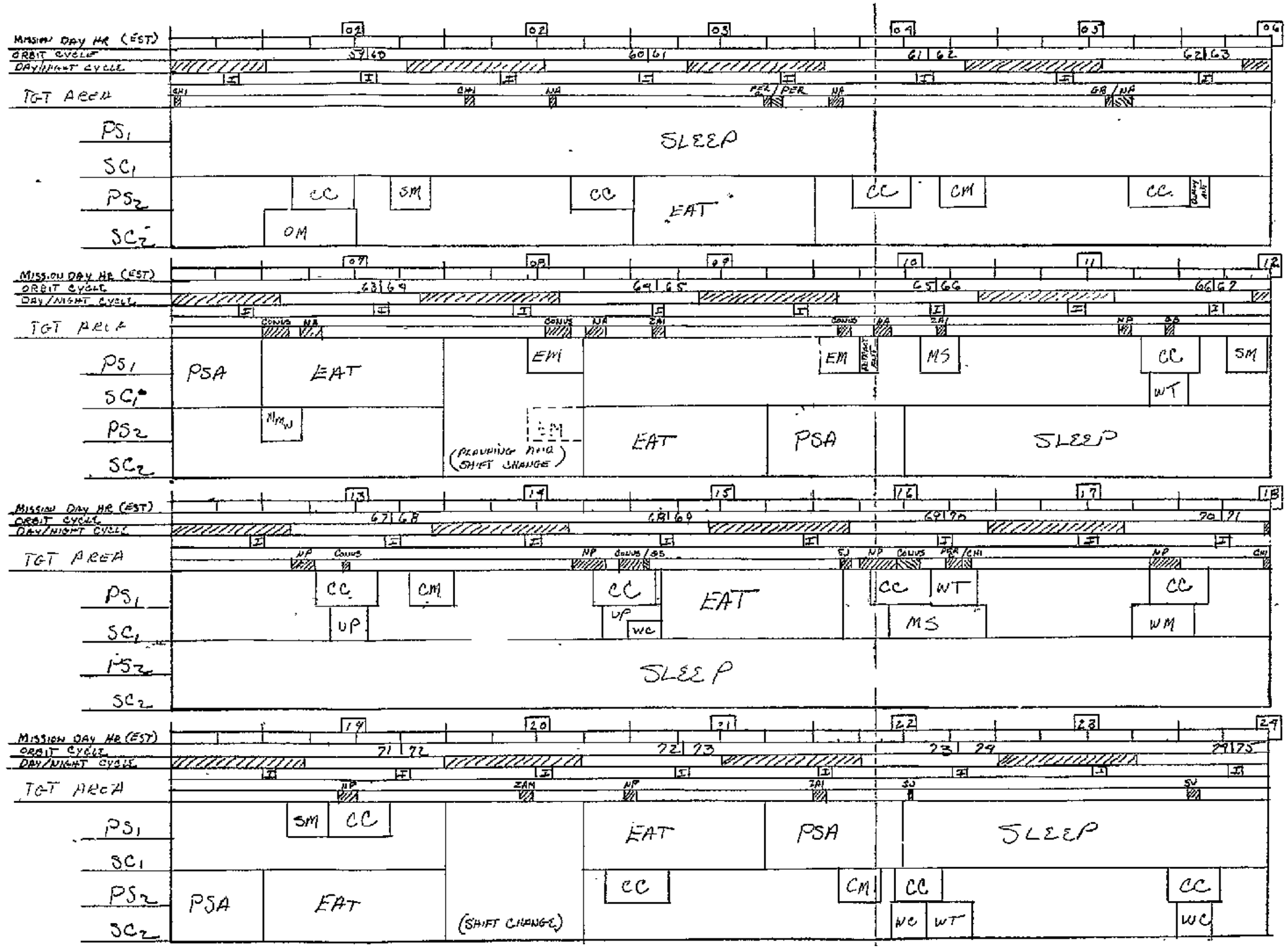
FOLDOUT FRAME 2

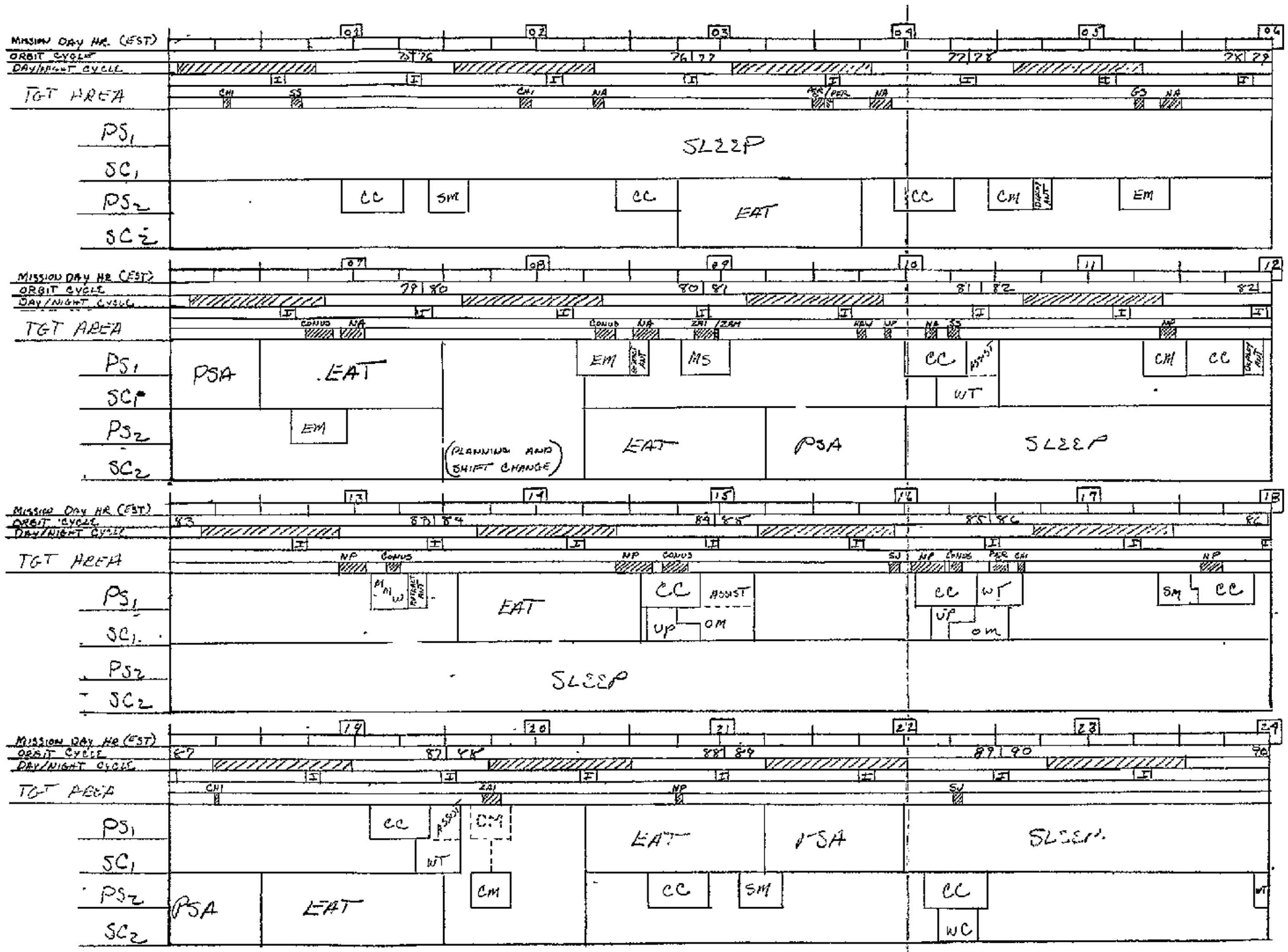
LAUNCH DATE ____
TIME ____
INCLINATION ____
ECCENTRICITY ____
PERIOD ____

MISSION DAY 1



LAUNCH DATE ______
TIME ______
INCLINATION ______
ECCENTRICITY ______
PERIOD ______

MISSION DAY 5



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LAUNCH DATE

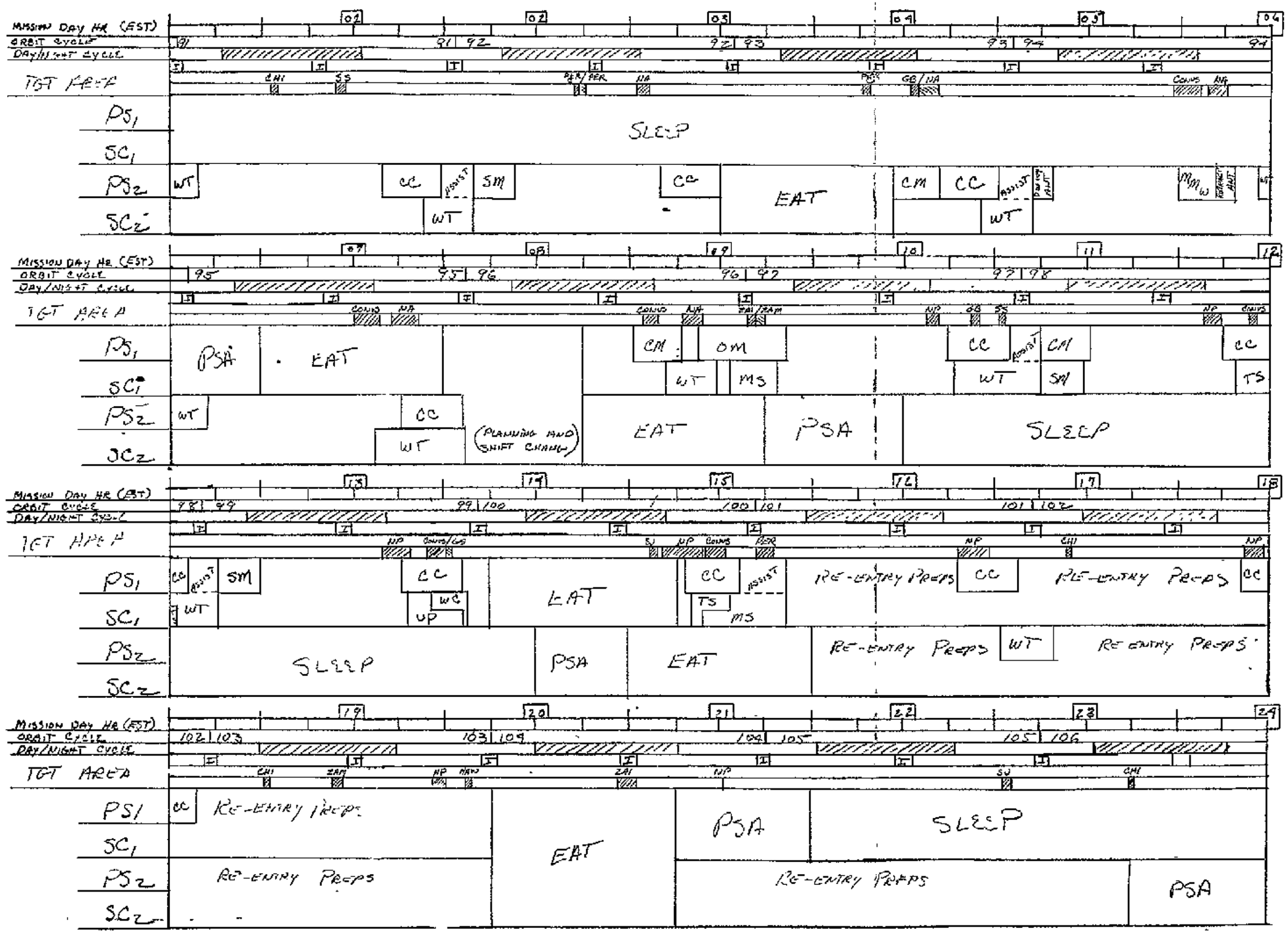
TIME

INCLINATION

ECCENTRICITY

PERIOD

MISSION DAY 6



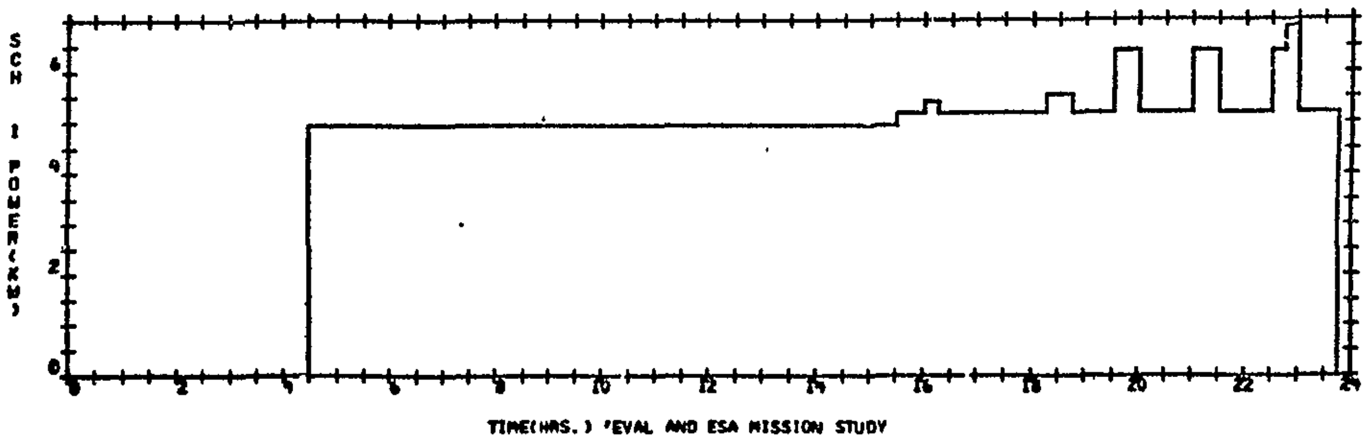
FOLDOUT FRAME 1

FOLDOUT FRAME 2

APPENDIX E

POWER PROFILE

ORGANIZATION:	MARSHALL SPACE FLIGHT CENTER	NAME: PD34/G. JOHNSON
PROGRAM DEVELOPMENT	EVAL PAYLOAD STUDY POWER PROFILE	DATE: SEPTEMBER 1, 1976



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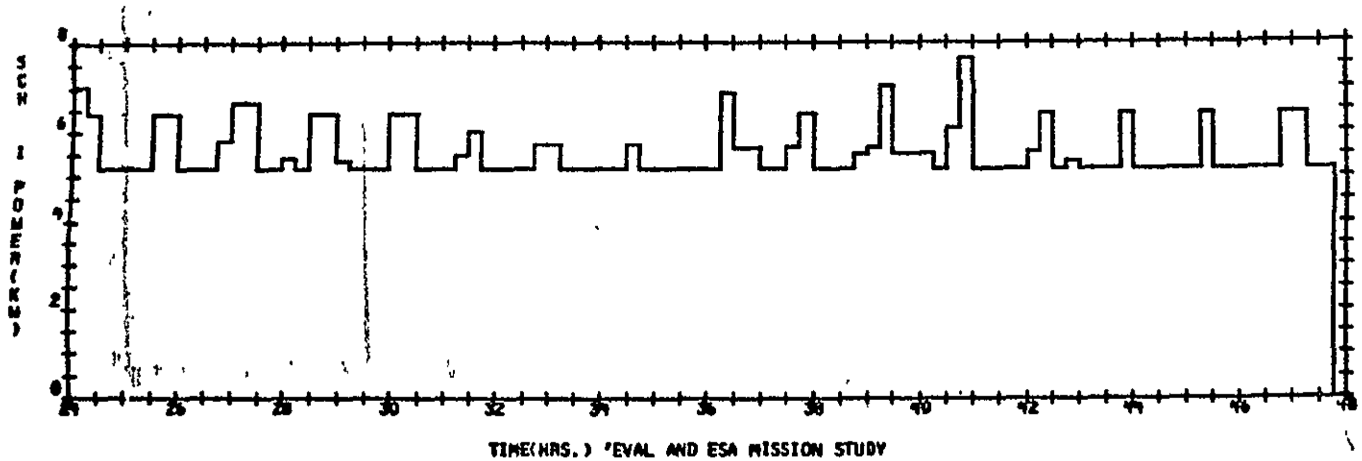
PROGRAM DEVELOPMENT	EVAL PAYLOAD STUDY POWER PROFILE	DATE: SEPTEMBER 1, 1976



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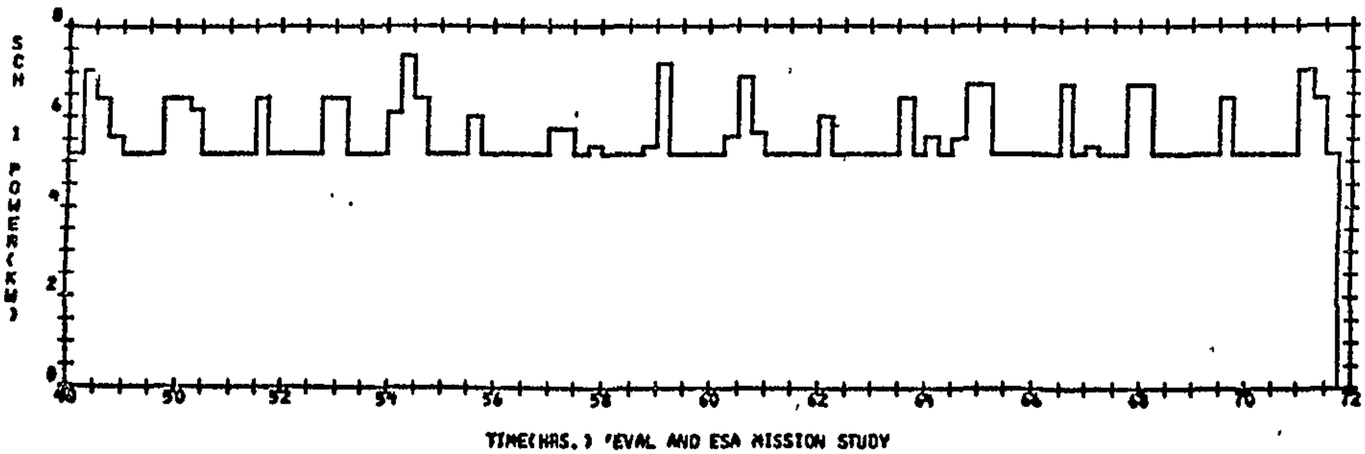
		DATE: SEPTEMBER 1, 1976



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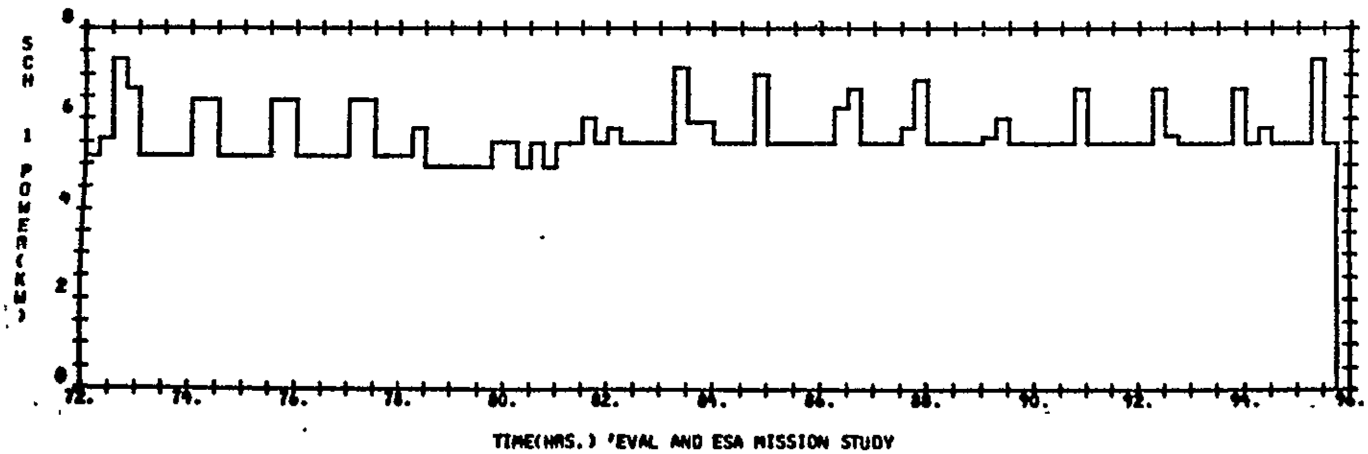

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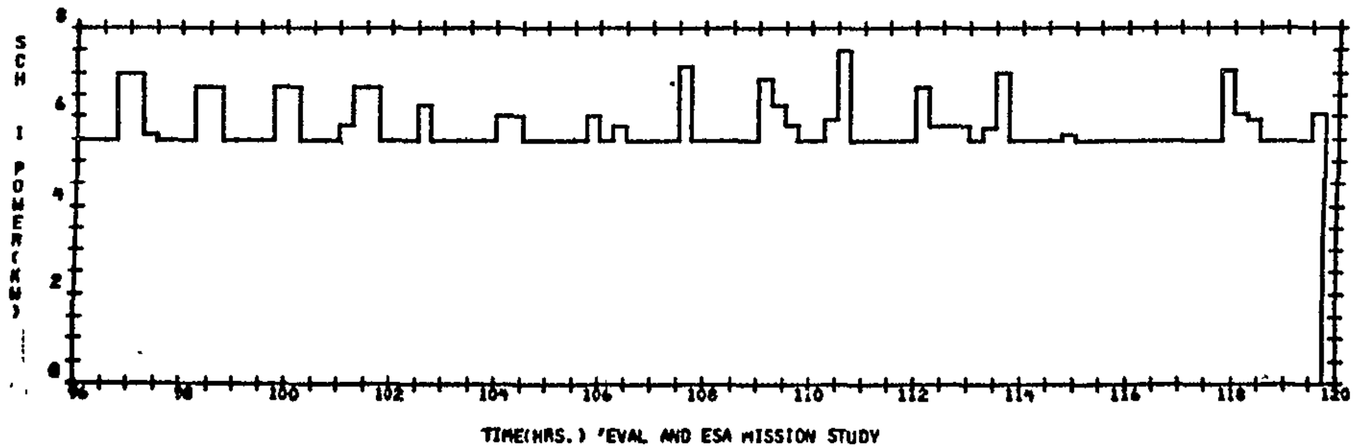
PROGRAM DEVELOPMENT	EVAL PAYLOAD STUDY POWER PROFILE	DATE: SEPTEMBER 1, 1976



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PROGRAM DEVELOPMENT	EVAL PAYLOAD STUDY POWER PROFILE	PD34/V. BURTON
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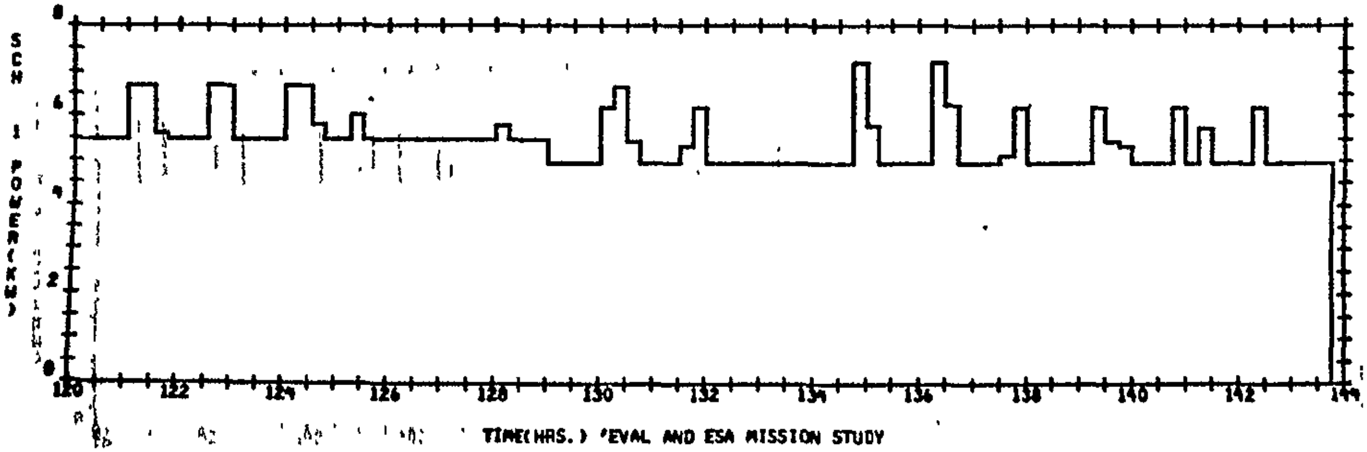

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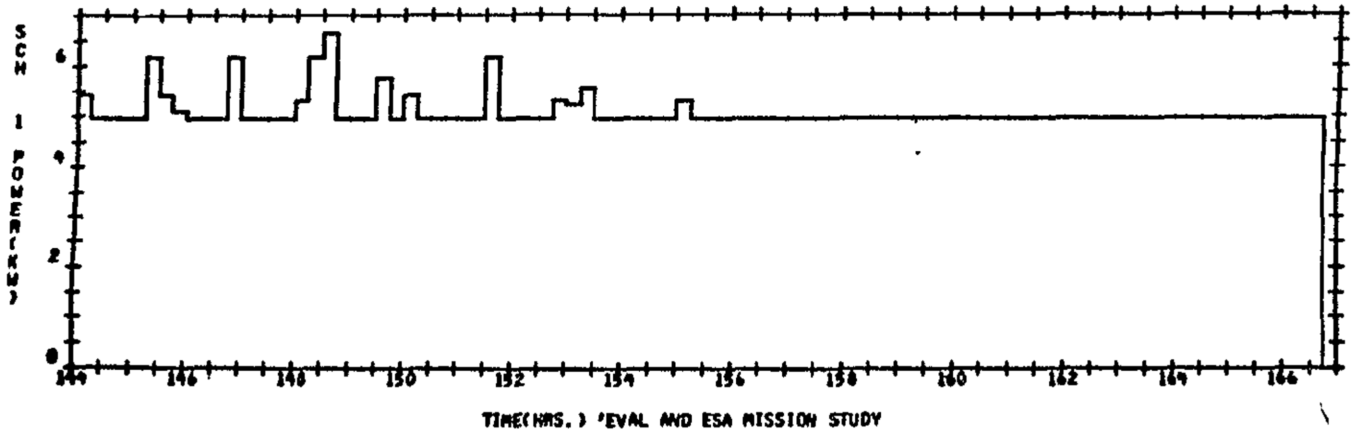

APPENDIX F

EVAL PAYLOAD VIBROACOUSTIC TEST PLAN EVALUATION

APPENDIX F

EVAL PAYLOAD VIBROACOUSTIC TEST PLAN EVALUATION

INTRODUCTION

This analysis applies the methodology being developed under Contract NAS 5-20906 for NASA-GSFC to evaluate cost effective vibroacoustic test plans for a representative EVAL Shuttle Spacelab payload. Statistical decision theory is used to quantitatively evaluate seven alternate test plans which include component, subassembly, or payload testing and combinations of component and assembly testing. The optimum component and assembly test levels and the expected cost of failures are determined for each test plan. By including the direct costs associated with each test plan and the probabilistic costs due to ground tests and flight failures, the test plans which minimize project cost are determined.

THE TEST PLANS

The test plans considered under Contract NAS 5-20906 are listed in Table 1. Test Plans 1-5 were considered as a group to develop the basic methodology. A multiple mission facility type payload was utilized. The results for that group of test plans are documented in GE document No. 76SDS4223, "Vibroacoustic Test Plan Evaluation", dated June 1, 1976. Based on the results of that study, the methodology is currently being expanded and the group of Test Plans 4-9 are being evaluated. This EVAL analysis is limited to Test Plans 4-9.

In the context of this study the term subassembly implies a group of functionally related components mounted on a common substructure that is testable at that level of assembly. System implies a fully integrated payload. The component tests are considered to be random vibration, which provides a good simulation of the effects of

Table 1 .

Vibroacoustic Test Plan Matrix

Test Plan No.	Component Test	Subassembly Test	System Test	Structure Test
1	Mix*	-	-	-
1A	Mix	-	-	SDM**
2	Mix	Protoflight	-	Protoflight
3	Mix	-	Protoflight	Protoflight
3A	Mix	-	Protoflight	SDM
4	-	Protoflight	-	Protoflight
5	-	-	Protoflight	Protoflight
6	-	-	-	-
7	Protoflight	-	-	-
7B	Protoflight	-	-	Protoflight
8	Protoflight	Protoflight	-	Protoflight
9	Protoflight	-	Protoflight	Protoflight

* Prototype housekeeping components and protoflight experiment components

** Prototype Structural Development Model

acoustic excitation at this level of assembly. Acoustics testing, which provides a good simulation of the flight conditions, is considered to be performed at the subassembly and system levels. Any test failure is assumed to result in redesign and retest. The test plans involve the evaluation of the change in vibroacoustic reliability of the payload as a result of one or two ground tests at the various assembly levels.

The structural design is varied on the basis of the structural test option considered. If no structural test is performed (Test Plans 6 and 7), an ultimate design safety factor of 2.0 is used. When the protoflight structure is tested (Test Plans 4, 5, 7B, 8, 9), an ultimate design safety factor of 1.5 is used. A 13 percent and a 35 percent increase in structural weight were considered for design safety factors of 1.5 and 2.0, respectively. The flight and test failure probabilities for the structure were determined from empirical data.

THE PAYLOAD CONFIGURATIONS

A representative Earth Viewing Applications Laboratory (EVAL) payload, Figure 1 was used for this analysis. Although the physical arrangement of the payload may preclude subassembly testing, Test Plans 4-9 are considered to be applicable. As in Contract NAS 5-20906, the payload is considered to be composed of a series of housekeeping components that are grouped into three subassemblies (power, control, data handling), the experiments, and the structure. Rather than study the 18 individual experiments planned for EVAL missions, the experiments were grouped according to the number of missions expected for each experiment. Within these groups the number of components peculiar to each experiment was averaged. This resulted in four configurations used in this analysis, Table 2 The basic payload parameters used in the analysis are defined in Table 3.

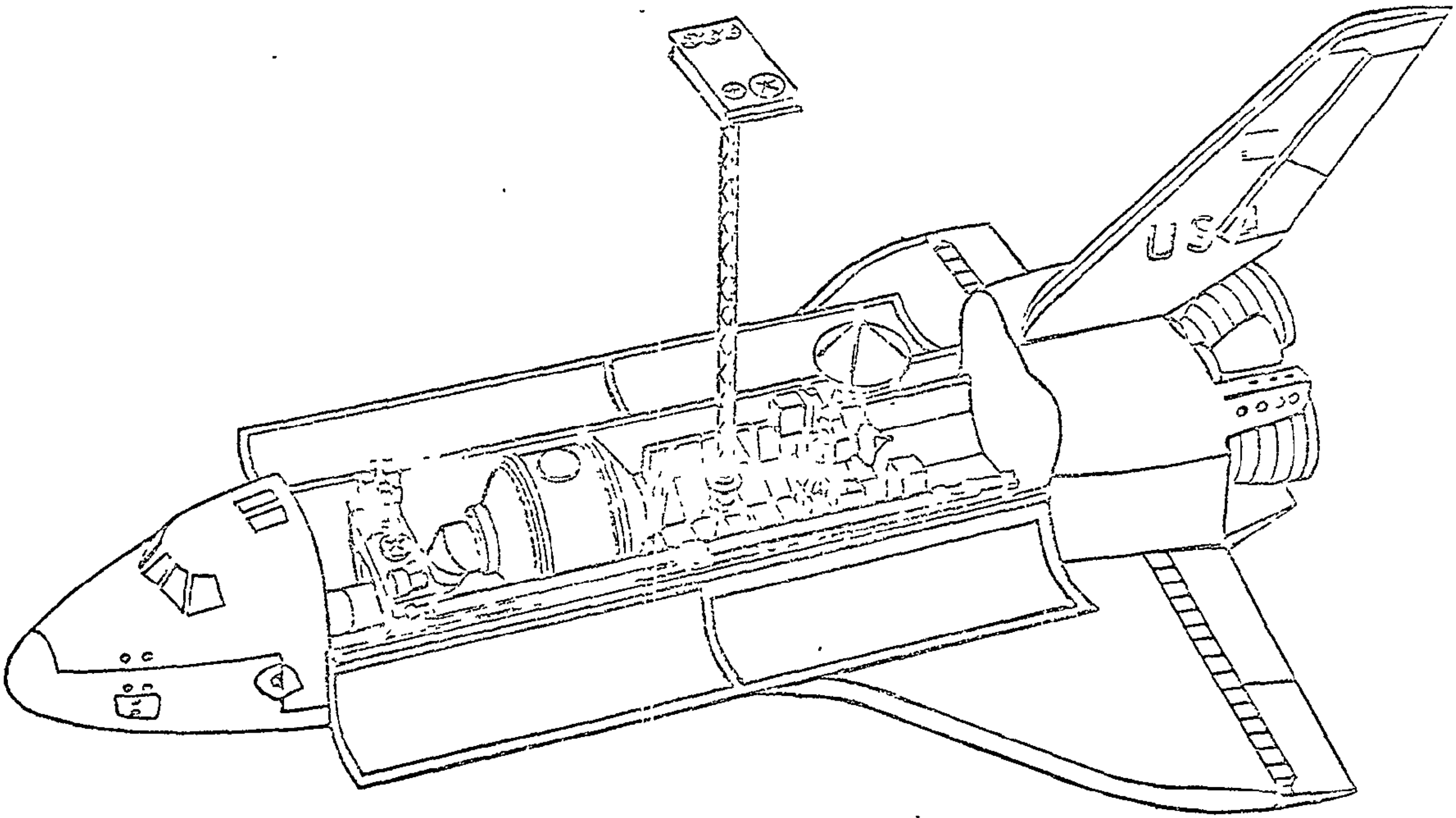

Figure 1- Typical Applications Payload

Table 2

Payload Configurations

Configuration	NEXP	NCPE	NF	Mission	$NCPE_i$
1	4	2	2	Multibeam Communications Bandwidth Compression Modulation Urban and Regional Planning Mineral Exploration	1 1 2 3
2	2	2	10	Geomagnetic Field Measurements Timber Inventory	1 3
3	6	4	20	Electromagnetic Mapping Cloud Climatology Crustal Motions Monitoring Water Inventory Sea Surface Temperature Ocean Waves and Currents	1 2 3 3 4 6
4	6	3	40	Ozone Sounding and Mapping Solar Energy Monitoring Troposphere Trace Constituents Coastal Zone Pollution World Crop Survey Stratospheric Pollution Mapping	1 1 2 3 4 5

where

NEXP = number of experiments

NCPE = number of components (sensors) peculiar to an experiment

NF = number of flights

Table 3

Payload Parameters

Total Equipment Weight	10000 pounds
Payload Length	40 feet
Number of flights	2, 10, 20, 40
Number of Housekeeping Components	16
Number of Housekeeping Subassemblies	3
Number of Experiments per Configuration	2, 4, 6
Number of Components per Experiment	2, 3, 4
Housekeeping Components	Protoflight
Experiment Components	Protoflight

THE RELIABILITY MODEL

The probability of achieving the flight objectives is needed to determine the expected cost of flight failures. A component flight failure does not always result in a complete loss of the mission. To determine the expected cost of a flight failure, a reliability model at the component level is used to estimate the probability of achieving a portion of the flight objectives. To estimate the probability of achieving the flight objectives the payload reliability model shown in Figure 2 is used. This model represents the payload as a series of redundant components and a group of parallel experiments. The series components represent the basic subsystems used for housekeeping functions; they are assumed to have single redundancy, except for the structure. These components are common to all experiments and are essential to the success of the flight. Each experiment contains a series of components which have no redundancy. The payload subassemblies are considered to be the experiments, the structure, and the three housekeeping subassemblies. The components in the housekeeping subassemblies are grouped as follows:

1. Power subassembly - 4 components
2. Control subassembly - 4 components
3. Data handling subassembly - 8 components

THE ENVIRONMENT

For this test plan evaluation the component test environment is based on the 145 dB shuttle payload bay acoustic spectrum and is related to the flight environment by the standardized vibration variable, U_V, which is the number of standard deviations from the mean. This 145 dB environment is defined to be the mean plus two sigma acoustic level with a standard deviation of 2 dB. The component test vibration level or design

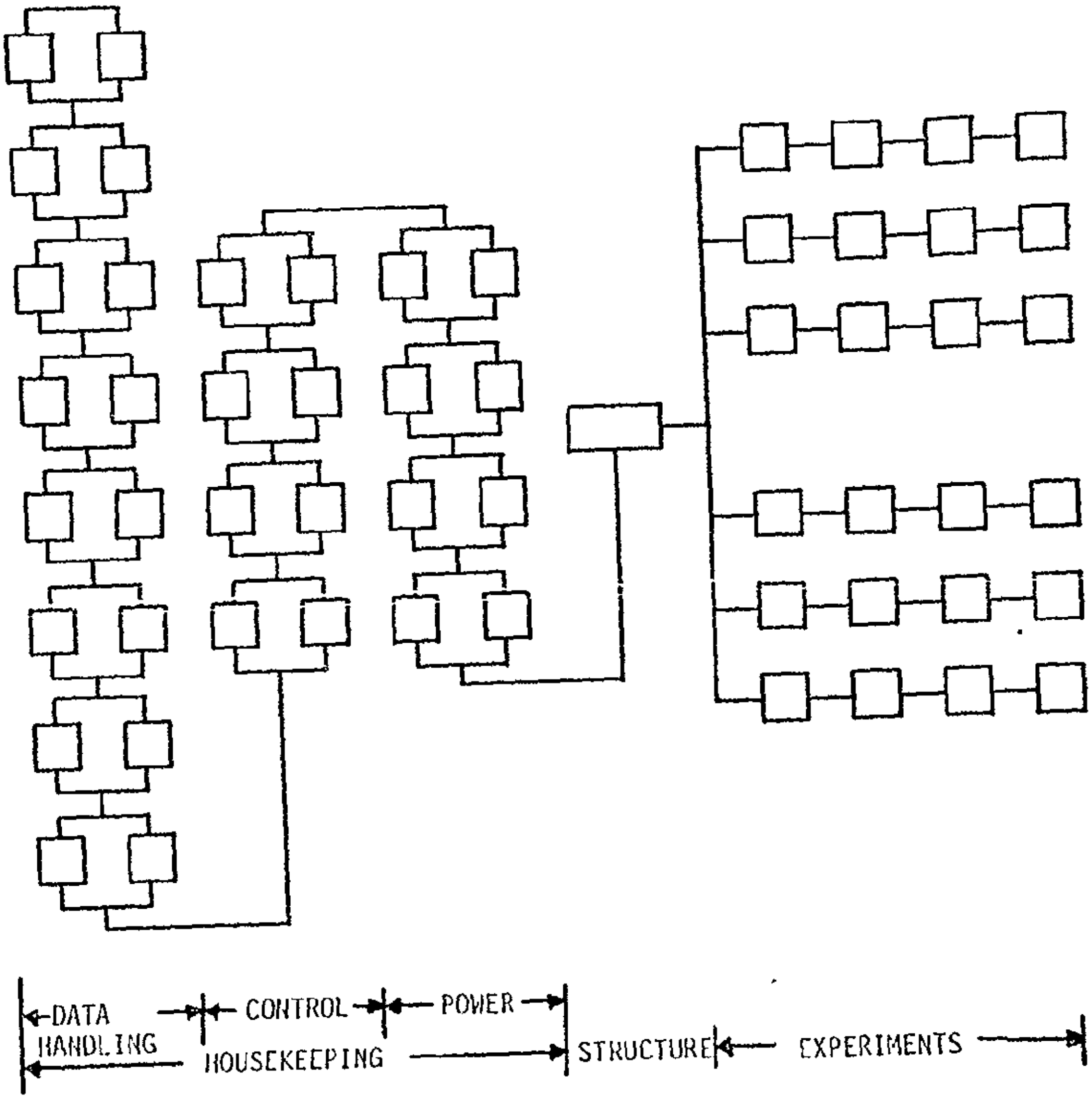

Figure 2 Reliability Model

requirement is varied from 8 to 104 g rms (U_V = 1.2 to 3.2) and the assembly test acoustic level is varied from 143 dB to 157 dB.

THE COSTS

When a particular test plan is selected there are some direct costs which are certain to be incurred. For each test plan these direct costs are summarized in Table 4 It is noted that direct costs common to all test plans do not need to be included since they will not affect the cost differences between the test plans. A direct cost associated with an increased weight due to designing with a higher safety factor is included. It is assumed that 20 percent of the total equipment weight is structure weight. Also included in this analysis is a direct cost associated with designing hardware to margins of safety in excess of those possible with conventional spacecraft.

The probabilistic costs are those costs that result from failures during ground testing and flight. A probabilistic cost is the sum of the products of the failure costs and the associated probability of occurrence. The probabilistic costs that are associated with the various test plans are also summarized in Table 4

The values used in this EVAL analysis for the various cost parameters are summarized in Tables 5 & 6 forthe direct costs and probabilistic costs, respectively.

TEST PLAN EVALUATION

Cost Optimization

The decision model for each test plan was exercised for the four EVAL payload configurations. The payload configuration complexity was varied by considering either 2, 4, or 6 experiments, with each experiment comprised of either 2, 3, or 4 serial

Table 4

Cost Summary

Cost Type	Cost Parameter	Test Plan 4	5	6	7	7B	8	9
Direct	Component Tests				X	X	X	X
	Subassembly Tests	X					X	
	System Tests		X					X
	Structure Tests	X	X			X	X	X
	Structural Weight	X	X	X	X	X	X	X
	Design Cost	X	X	X	X	X	X	X
Probabilistic	Component Test Failures				X	X	X	X
	Subassembly Test Failures	X					X	
	System Test Failures		X					X
	Structural Test Failures	X	X			X	X	X
	Flight Failures	X	X	X	X	X	X	X

Table 5

Direct Cost Parameter Summary

Cost Parameter	Test Plan						
	4	5	6	7	7B	8	9
Component Test	-	-	-	8.	8.	8.	8.
Subassembly Test	21.	-	-	-	-	21.	-
System Test	-	199.	-	-	-	-	199.
Protoflight Structure Test	32.	32.	-	-	32.	32.	32.
Structural Weight (per pound)	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Component Design Cost	*	*	*	*	*	*	*

* Component Design Cost = $\frac{1800}{(100. - g)} - 20 \qquad 10 \leq g \leq 100$

where g is the component design/test level

NOTE: Costs are given in thousands of dollars

Table 6

Probabilistic Cost Parameters Summary

Cost Parameter	Test Plan						
	4	5	6	7	7B	8	9
Cost of Component Test Failure Redesign/Retest	-	-	-	15	15	15	15
Cost of Subassembly Test Failure Redesign/Retest	50	-	-	-	-	50	-
Cost of Flight Failure Redesign/Retest	50	50	50	50	50	50	50
Cost of Subassembly Functional Test	13	-	-	-	-	13	-
Subassembly Test Failure Cost Factor	120	-	-	-	-	120	-
Cost of Protoflight Structure Failure, Subassembly Testing	150	-	-	-	-	150	-
Cost of Protoflight Structure Failure, Payload Testing	-	240	-	-	-	-	240
Payload Test Failure Cost Factor	-	120	-	-	-	-	120
Cost of One Launch	17000	17000	17000	17000	17000	17000	17000
Cost of Additional Functional Test After Refurbishment	16	16	16	16	16	16	16

NOTE: Costs are given in thousands of dollars.

components, and each configuration being flown on either 2, 10, 20 or 40 flights. The housekeeping section of the payload was not changed; it consisted of the power, control, and data handling subassemblies having a total of 16 redundant components and the structure.

The expected cost was obtained as a function of the component vibration level and the applicable assembly acoustic test level. The vibration level has a dual meaning. For those test plans having component testing, the vibration level is the component random vibration test level. For those test plans that do not include component testing (Test Plans 4, 5, 6), it represents the component design requirement. The component strength distribution is considered to be a function of the component design/test level so that the vibration strength of the untested components continually increases as the vibration level is increased. Associated with this increase in strength as the vibration level is increased is the increase in the cost of designing the components to the higher level.

Optimum component and assembly test levels are clearly defined for all test plans for Configurations 2, 2, 10 and 6, 4, 20. For Configuration 4,2,2 the expected costs showed a continual increase as the assembly acoustic test level increased, indicating the optimum assembly test level is 143 dB or lower. For Configuration 6,3,40 the expected costs showed a continual decrease as the assembly acoustic test level increased, indicating the optimum assembly test level is 157 dB or higher. At each assembly test level for these two configurations, however, there is a clearly defined optimum component test level. It should be noted that optimums are obtainable for all test plans of this analysis because the component design cost was considered. This cost was not included in the earlier study documented in GE document 76SDS4223. These

optimums are summarized by test plan and payload configuration in Tables 7 and 8, respectively.

Comparison of the expected costs for the optimum test levels indicates that, for all of the payload configurations analyzed, minimum cost is achieved with Test Plan 4, which uses subassembly testing only, and Test Plan 5, which uses system testing only. The cost rank of the other test plans varies with the configuration. Except for Configuration 4,2,2, Test Plan 8, which uses both component and subassembly testing, ranks next, followed by Test Plan 9, which uses both component and system testing, Test Plan 7B, which uses only component testing, and either Test Plan 7, which also uses only component testing but no structure testing, or Test Plan 6, which uses no testing. For Configuration 4,2,2, Test Plan 6 ranks third, followed by Test Plans 8, 7B, 9, and 7.

The optimum test levels do not vary in the same manner as the optimum costs. However, the optimum levels for all test plans increase as the number of flights increases. The optimum expected cost also increases as the number of flights increases.

Comparison of the optimum expected costs for Test Plans 7 and 7B indicates that the protoflight tested structure is more cost effective than no structural test. The cost saving increases as the number of flights increases ($0.2M for 2 flights; $0.9M for 10 flights; $1.9M for 20 flights; $2.7M for 40 flights).

The major cost elements involved in establishing the optimum test levels are of interest. For Test Plans 4 and 5 the optimum results from combining the increasing design cost with the decreasing costs of assembly test failures and flight failures. For Test Plan 6 the increasing design cost interacts with the decreasing costs of flight failures. For Test Plans 7 and 7B the increasing design cost and costs of component test failures interact with the decreasing costs of flight failures.

Table 7

Summary of Optimums by Test Plan

Test Plan	Payload Configuration (NEXP,NCPE,NF)	Expected Cost ($ x 10^6)	Component Vibration Level (g rms)	Assembly Acoustic Level (dB)	Vibroacoustic Reliability
4	4,2,2	0.561	22.5	143.	0.9887
	2,2,10	1.283	29.0	151.	0.9975
	6,4,20	2.818	29.0	155.	0.9896
	6,3,40	4.265	37.4	157.	0.9921
5	4,2,2	0.787	22.5	143.	0.9887
	2,2,10	1.664	29.0	149.	0.9961
	6,4,20	3.398	37.4	153.	0.9855
	6,3,40	4.906	37.4	157.	0.9921
6	4,2,2	1.354	37.4	-	0.8943
	2,2,10	4.539	62.4	-	0.9672
	6,4,20	12.472	62.4	-	0.8256
	6,3,40	19.106	80.6	-	0.8934
7	4,2,2	1.731	22.5	-	0.9457
	2,2,10	4.602	48.3	-	0.9816
	6,4,20	12.005	62.4	-	0.8980
	6,3,40	20.526	62.4	-	0.8831
7B	4,2,2	1.550	22.5	-	0.9464
	2,2,10	3.676	48.3	-	0.9823
	6,4,20	10.134	62.4	-	0.8986
	6,3,40	16.768	62.4	-	0.8837
8	4,2,2	1.361	13.5	143.	0.9830
	2,2,10	2.112	22.5	151.	0.9973
	6,4,20	4.148	22.5	155.	0.9890
	6,3,40	5.513	29.0	157.	0.9919
9	4,2,2	1.674	13.5	143.	0.9830
	2,2,10	2.527	22.5	149.	0.9957
	6,4,20	4.814	29.0	153.	0.9849
	6,3,40	6.175	29.0	157.	0.9919

Table 8

Summary of Optimums by Payload Configurations

Payload Configuration (NEXP,NCPE,NF)	Test Plan	Expected Cost ($ x 10^6)	Component Vibration Level (g rms)	Assembly Acoustic Level (dB)	Vibroacoustic Reliability	Cost Rank	Reliability Rank
4,2,2	4	0.561	22.5	143.	0.9887	1	1
	5	0.787	22.5	143.	0.9887	2	1
	6	1.354	37.4	-	0.8943	3	7
	7	1.731	22.5	-	0.9457	7	6
	7B	1.550	22.5	-	0.9464	5	5
	8	1.361	13.5	143.	0.9830	4	3
	9	1.674	13.5	143.	0.9830	6	3
2,2,10	4	1.283	29.0	151.	0.9975	1	1
	5	1.664	29.0	149.	0.9961	2	3
	6	4.539	62.4	-	0.9672	6	7
	7	4.602	48.3	-	0.9816	7	6
	7B	3.676	48.3	-	0.9823	5	5
	8	2.112	22.5	151.	0.9973	3	2
	9	2.527	22.5	149.	0.9957	4	4
6,4,20	4	2.818	29.0	155.	0.9896	1	1
	5	3.398	37.4	153.	0.9855	2	3
	6	12.472	62.4	-	0.8256	7	7
	7	12.005	62.4	-	0.8980	6	6
	7B	10.134	62.4	-	0.8986	5	5
	8	4.148	22.5	155.	0.9890	3	2
	9	4.814	29.0	153.	0.9849	4	4
6,3,40	4	4.265	37.4	157.	0.9921	1	1
	5	4.906	37.4	157.	0.9921	2	1
	6	19.106	80.6	-	0.8934	6	5
	7	20.526	62.4	-	0.8831	7	7
	7B	16.768	62.4	-	0.8837	5	6
	8	5.513	29.0	157.	0.9919	3	3
	9	6.175	29.0	157.	0.9919	4	3

For Test Plans 8 and 9 the increasing design cost and costs of component test failures interact with the decreasing costs of assembly test failures and flight failures.

Reliability and Cost Optimization

In Tables 7 and 8 the payload flight vibroacoustic reliabilities associated with the optimum expected costs are also indicated. In this analysis the flight vibroacoustic reliability is defined as the probability of no data loss from the payload as a result of a vibration failure of a component. For all of the payload configurations analyzed, the test plan with the minimum cost, Test Plan 4, also has the maximum reliability. Except for Configuration 6,3,40, Test Plan 6, which uses no testing, has the lowest reliability. Within these bounds the reliability rank varies with the configuration. For all test plans Configuration 2,2,10 has the highest reliability, but the configuration with the lowest reliability varies from test plan to test plan. The low flight reliability of Test Plan 6 is consistent with its being, together with Test Plan 7, the least cost effective.